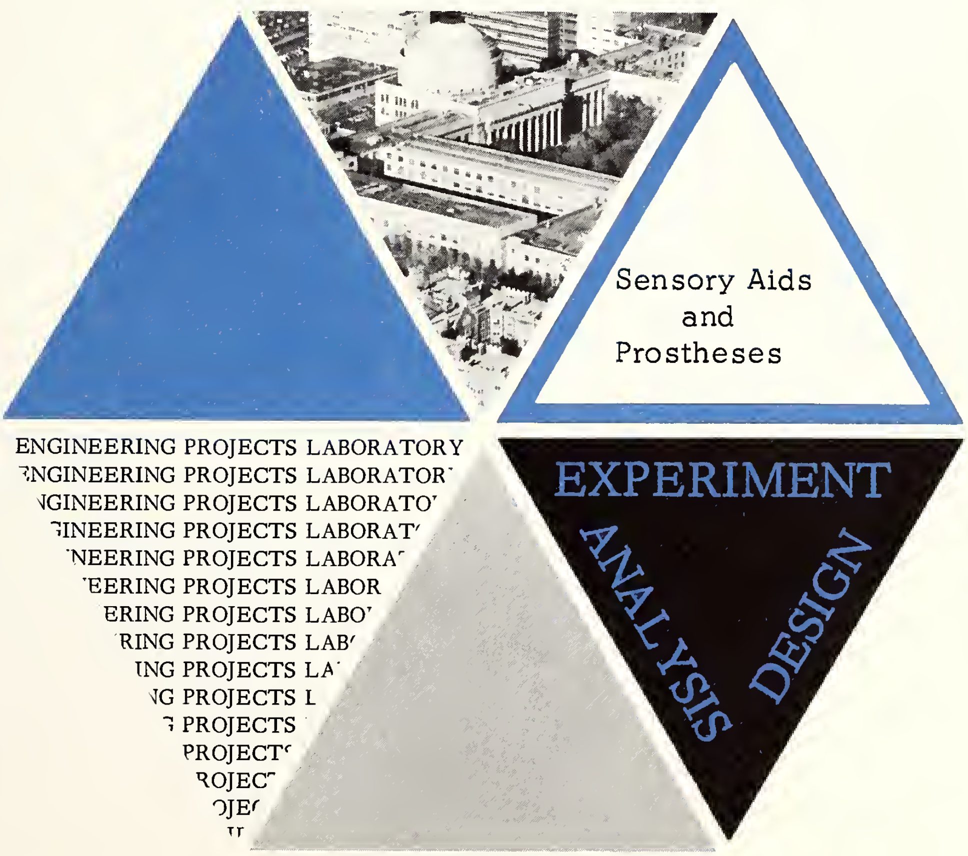
DEVELOPMENT OF A PUNCHED-TAPE-TO-BRAILLE "DIRECT" AND CONTINUOUS MECHANICAL TRANSDUCER

Ernesto E. Blanco

Report No. 70249-4

June 1968

Engineering Projects Laboratory
Department of Mechanical Engineering
Massachusetts Institute of Technology



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Social and Rehabilitation Services
Department of Health, Education and Welfare

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1. ACKNOWLEDGEMENTS

The work presented in this report was initiated in June 1961 by the author while he was a faculty member of the Design Division of the Mechanical Engineering Department at M. I. T. Design, development and initial evaluation continued at M. I. T. under the author's supervision with the colloboration of M. I. T. students and staff during the period 1961 through June 1964 when the author joined the faculty of the Design and Graphics Department in the School of Engineering at Tufts University. Since then he has continued his association with the project conducting further evaluation and preparing this report.

The work presented here was sponsored by the Vocational Rehabilitation Administration (now part of the Social and Rehabilitation Service) of the Department of Health, Education and Welfare under contract with the Division of Sponsored Research of the Massachusetts Institute of Technology.

Ultimate supervision of this project was the responsibility of Professor Robert W. Mann of the Design Division, Department of Mechanical Engineering, at the Massachusetts Institute of Technology. Professor Mann's experiences working with the blind provided a wealth of information not otherwise available. His able and sympathetic guidance was of immense assistance throughout the entire execution of this project.

The late Mr. John K. Dupress, inaugural Director of the M. I. T. Center for Sensory Aids contributed valuable suggestions and constructive criticisms during the evolution of the various prototypes as well as in the informal evaluation of the final model.

Mr. Kai F. Johansen, a graduate student, was responsible for the investigation of the by-stable plastic bubble braille bump simulator and for the fabrication of the first prototype of the intermittent, or Line-at-a-time, direct transducer. An undergraduate student, Mr. John Holly, assisted

during the fabrication of the continuous direct transducer and proposed a program for the psychophysical evaluation of the system in the course of his thesis work.[1]

Mr. Clarence W. Christiansen, supervisor of M. I. T. Mechanical Engineering Shop made important contributions during the fabrication of the prototypes, along with Mr. Aubrey Rigby of the Mechanical Engineering Machine Shop. Mr. Rigby's dedication and ingenuity made possible the fabrication of a durable transducer belt, and many other needed improvements.

The author wishes to express his most sincere gratitude to these collaborators for the assistance received during the execution of this project.

2 - PROJECT BACKGROUND -

The development of the machine described in this report began at the Design Division of the Mechanical Engineering Department at M. I. T. in June 1961 when this author was instructed to investigate possible means of displaying braille information from punched paper tape.

A preliminary analysis of the problem situation was performed, followed by a review of the state of the art in the field of braille display systems and a first order evaluation of various proposed approaches. Previous work done at M. I. T. and other institutions was appraised, along with ideas proposed by individual investigators.*

From the study of previous work it was concluded that most approaches, although simple in basic concept, were saddled to a variety of complex support systems such as electronic, electro-mechanical, or pneumatic accessories. While it was understood that such approaches were of laboratory character and later to be simplified it remained questionable whether their ultimate configuration would have the characteristics of simplicity, sturdiness, and low cost, sought in devices for widespread use by the blind.

Based on the aforementioned initial study it was decided to approach the solution of the problem by intently working from the simple, or even crude, toward the more sophisticated concepts, always bearing in mind that the accessibility and simplicity of the ultimate product were, in this case, almost as important as its basic function.

After the initial studies several new ideas were evolved, and feasibility experiments were performed on the three most promising

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*See bibliography at end of this report.

concepts. The result of those preliminary investigations indicated the advisability of pursuing the development of a "direct"* type of entirely mechanical transducer without decoding features in preference over "indirect"†, and electro-mechanical systems.

A discussion of the evolution of preliminary concepts, feasibility studies, and the ultimate development of a transducer prototype intended for psychophysical evaluation constitute the objective of this report.

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* In the direct transducer the punched tape is "read" directly by the tactile stimulators which in fact perform simultaneously the dual function of information retrieval and braille display.

† In the indirect transducers the functions of information retrieval and display are performed by separate elements interlocked through intermediate components. These systems are almost inevitably more complex than the direct types.

3 - IDENTIFICATION OF NEED - [2]

Present day production of braille reading material is slow, costly, and the resulting texts are bulky and awkward when compared to common inkprint for the sighted. Additional problems of transcription, storage, and a limited market have resulted in an enormous disparity between the availability of embossed braille and regular inkprint.

Under such conditions blind readers find themselves at a great disadvantage when depending on reading material. Blind people are assuming increasingly responsible occupations in industry and the professions. The successful development of the new tasks of the blind in society demands a narrowing, and hopefully a closing, of the gap between the availability of inkprint and embossed braille.

4 -PROBLEM ANALYSIS -

Present data on the needs of braille by the blind is not totally reliable. Some blind subjects definitely prefer recordings or "talking books" over braille texts. Some prefer recordings for nontechnical subjects and rather use braille for more abstruse material. However, in spite of the availability of aural reading aids in many fields, the blind still depend heavily on braille texts. This seems particularly true in the professions. Moreover, there is evidence of greater retention of material when learned from braille rather than from aural inputs. Some subjects stress the advantage of re-reading words or whole sentences for better understanding when using braille.

There is also a strong possibility that an expanded availability of braille will not only contribute to the satisfaction of the present needs of the blind but will also facilitate the development of their reading skills, thereby widening their intellectual horizons.

5 - SOURCES OF BRAILLE MATERIAL -

At present, braille material is produced by the following methods:

a) Braille typewriters which produce original embossed pages and possibly one inferior quality copy.

b) Production printing presses using embossing metal plates.

c) Plastic or raised ink deposition processes which form the braille "bumps" by addition of material instead of embossing. These processes are used mostly in England, never having gained popularity in the United States.

Limited production of braille from regular inkprint is usually the work of sighted braille transcribers operating embossing typewriters. Those braille transcribers are mostly volunteers and their number is insufficient to satisfy but a very small fraction of the present needs. The capacity of braille industrial printing presses is also insufficient, although this problem is being slowly corrected.

6 - OTHER POSSIBLE SOURCES OF BRAILLE MATERIAL -

A reconsideration of the present situation suggests that , since most reading material to be processed into braille has at some time prior existence as regular inkprint, the use of some form of direct transcription from inkprint into braille should be considered as a way to facilitate production. However, no such system has yet been adequately developed owing to the extreme difficulties involved in the machine interpretation of printed characters and the subsequent translation of the information into the highly contracted Grade 2 braille, which is the most commonly used.

While the problems of machine interpretation and transcription of inkprint are being investigated, another interesting approach becomes

apparent. Most of the information content used in inkprint processes today is previously available in encoded, machine interpretable form, such as perforated tape, etc. for use in the typesetting processes. The availability of information in such form makes it possible to sidetrack the machine interpretation of inkprint by obtaining the information directly from the typesetter's source, which is usually a type compositor's perforated tape. Such tapes could be machine transcribed into a form that could easily lend itself to conversion into braille by means of simple, individually owned, transducers.

The process explained previously would have the following advantages. a) Up to date information, such as news material or new books, could be made available to blind subscribers by simply transcribing Teletypesetter or type compositor tapes. b) Transducer tapes would carry a much higher information content per unit volume than common embossed braille pages since there would be no bumps or heavy stock sheets. c) Only one transcription facility from type compositor tapes to transducer tapes could produce an indefinite number of tape copies according to demand. d) Properly encoded information in magnetic storage form could be quickly transformed into transducer tapes thus reducing enormously the size of libraries for the blind.

The transducer described in this paper is intended to provide the braille output of a system such as the one just described.

7- PROJECT GOAL -

Design of a simple transducer to take perforated tape input in convenient coded form and convert it to a braille display.

8- PRELIMINARY TASK SPECIFICATIONS -

The specifications listed below represent the "desired" or "ideal" characteristics of the system sought.

1. The system should take perforated tape such as standard computer tapes as input.

2. The input tapes should be easy to load and remove from the machine by a blind operator.

3. Input tapes should require no complex decoding within the machine.

4. The displayed length of braille lines should be comparable to those in braille books, ranging from 9" to 11".

5. Tactile stimulus to reader should be similar to that of regular embossed braille.

6. Reading surfaces should be non-corrosive.

7. Machine dimensions should be within the envelope size of a portable typewriter.

8. Maximum weight should be less than 15 pounds.

9. Manufacturing cost should be kept below $100.

10. Braille display rate should be between 10 and 200 words/min.

11. Machine strength and durability should be comparable to those of an ordinary typewriter.

12. Speed of operation should be controlled easily in either forward or backward direction to allow rereading.

13. Design should allow either manual or power operation.

14. In addition to these characteristics it is desirable that the system be as free from operational complexities as possible.

15. System should be assembled in such way as to permit ease of adjustments and repair at owner's premises.

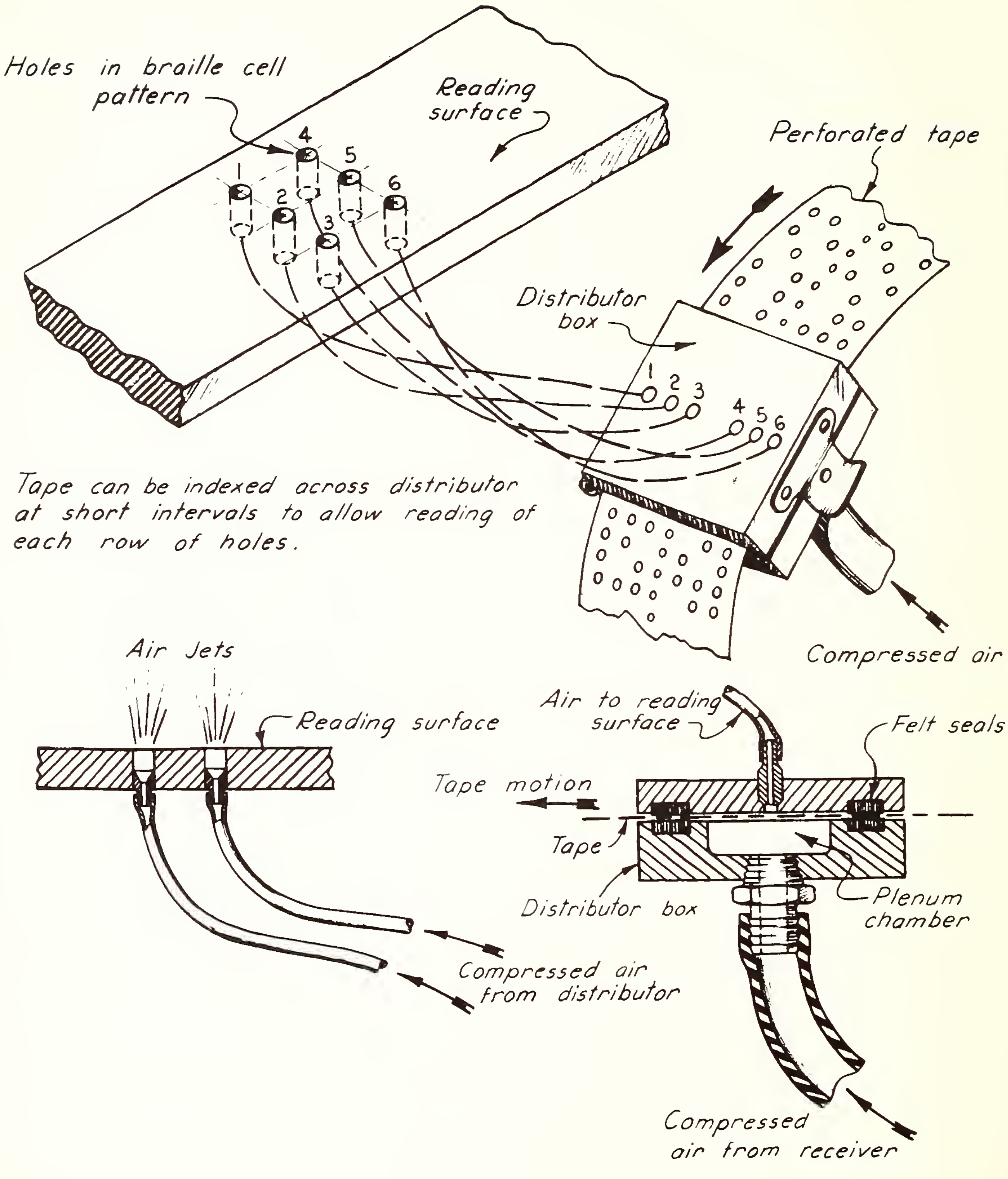
9- EVOLUTION OF CONCEPT — ANALYSIS PHASE -

It is customary in a work of this type to present and discuss only the final concept upon which the bulk of the work is based. Such procedure, while acceptable for its brevity, leaves behind in total obscurity a wealth of preliminary work which could be extremely valuable to future investigators by helping to reduce duplication of conceptual activity and providing seminal ideas for further research.

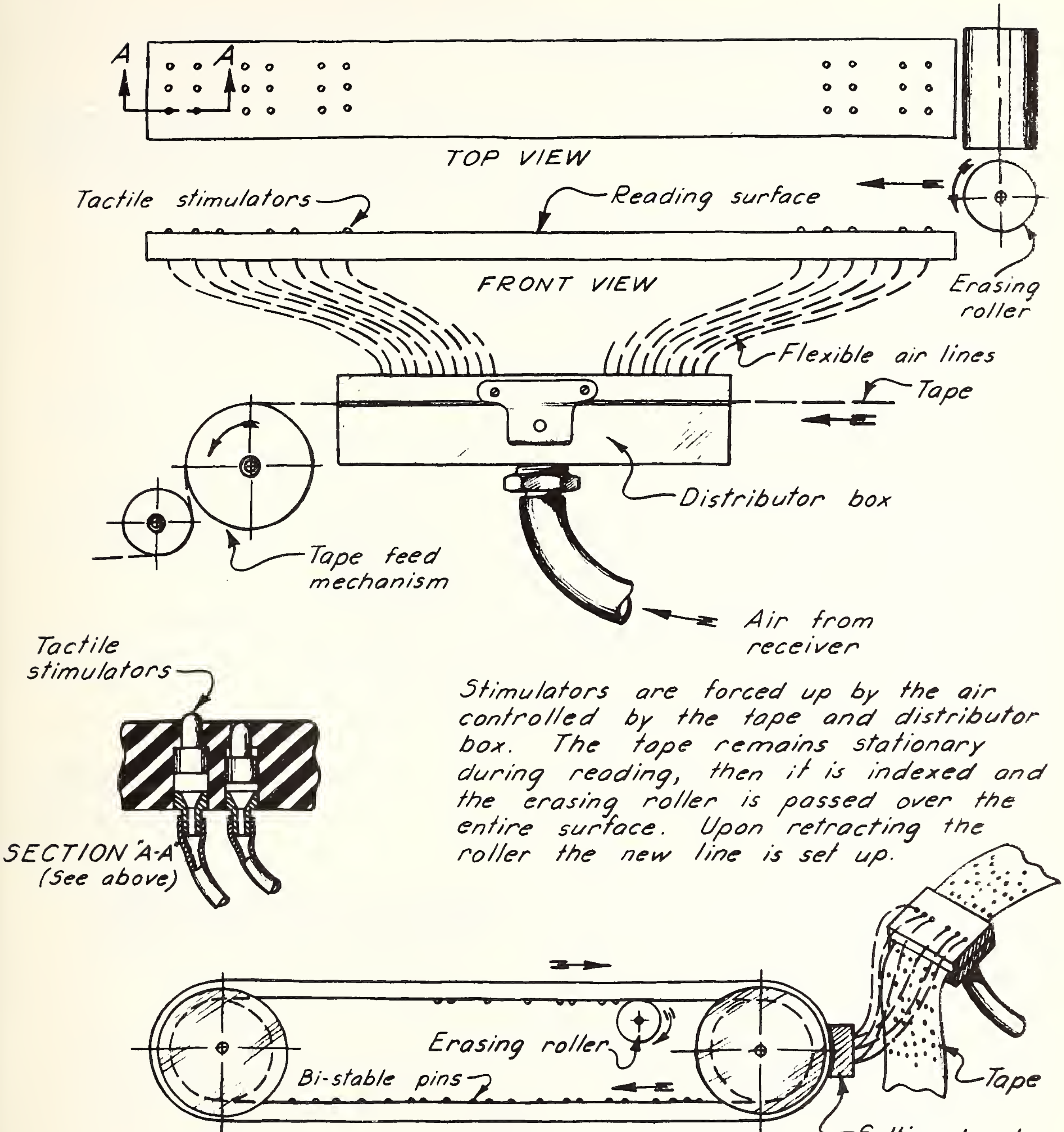
The work presented here describes the evolution of concepts from the start of the project to the initial feasibility prototype studies from which only two concepts were selected as theoretically promising. While there is no question regarding the advisability of investigating other approaches, it seems good to point out that the concept selection in this case was based primarily on expected ultimate simplicity and low cost considerations. See Figures 1 through 6 (on pages 10 through 15).

It is hoped that in the future better approaches will be developed leading to an ever improving solution for the problem confronted.

-CONCEPTS CONSIDERED-



- FIGURE 1 -

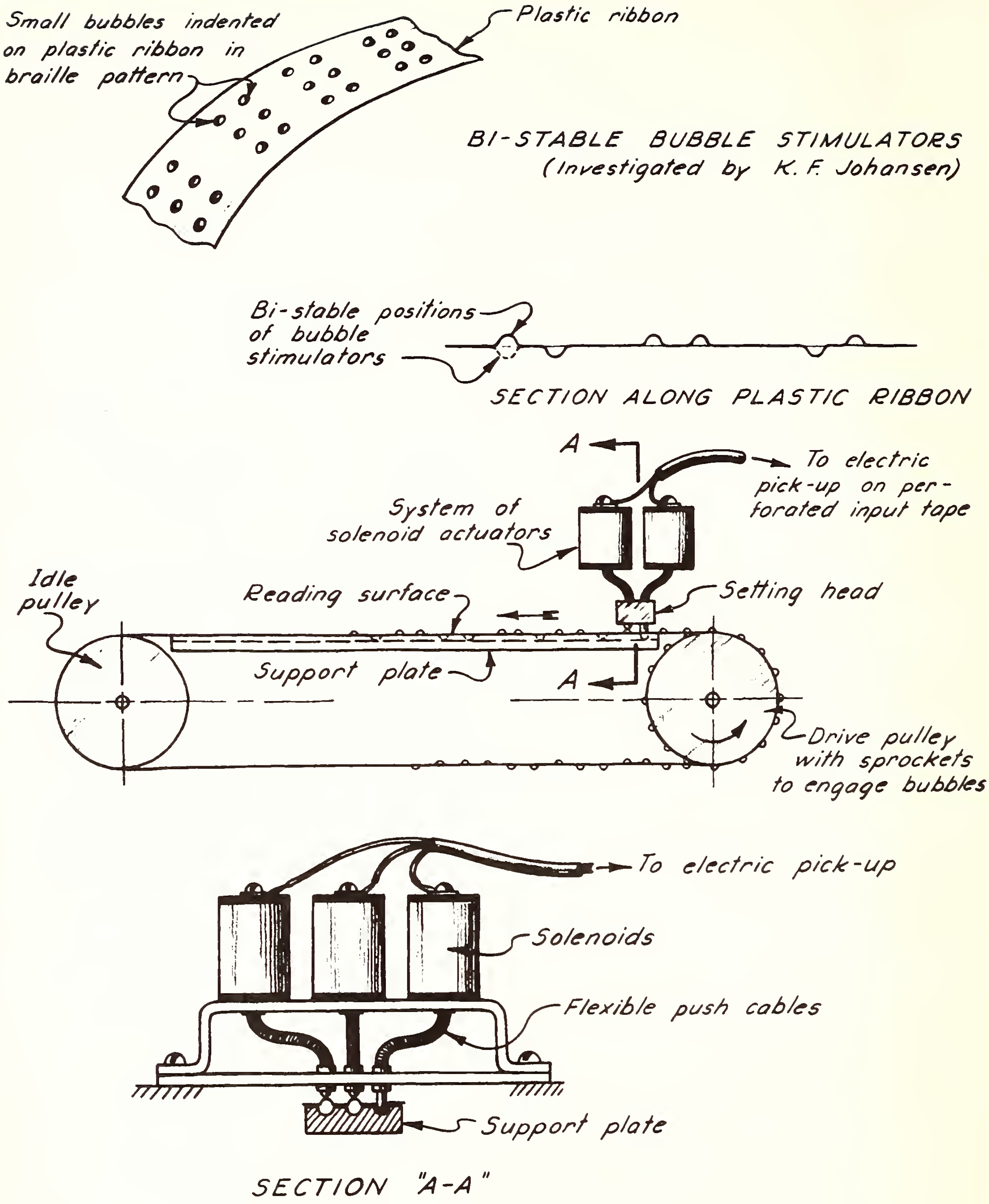


Stimulators are forced up by the air controlled by the tape and distributor box. The tape remains stationary during reading, then it is indexed and the erasing roller is passed over the entire surface. Upon retracting the roller the new line is set up.

ENDLESS BELT SYSTEM

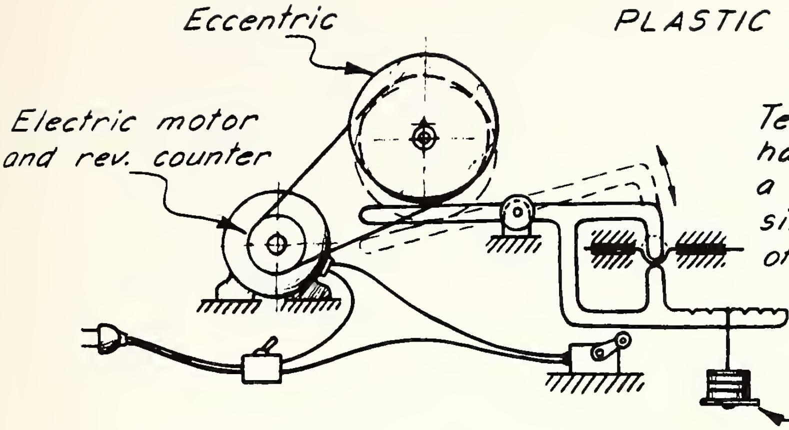
In this system a flexible endless belt carries an array of bi-stable pins forming a series of braille cell patterns, the pins being held to the belt by friction. A pneumatic setting head is used to position the pins and an erasing roller retracts them.

- FIGURE 2 -

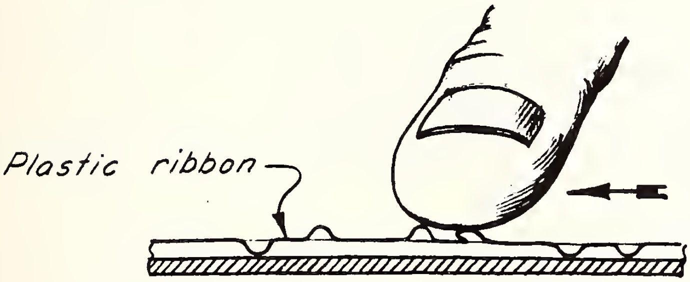

Small bubbles indented on plastic ribbon in braille pattern
Plastic ribbon
BI-STABLE BUBBLE STIMULATORS
(Investigated by K.F. Johansen)
Bi-stable positions of bubble stimulators
SECTION ALONG PLASTIC RIBBON
A
To electric pick-up on perforated input tape
System of solenoid actuators
Idle pulley
Reading surface
Setting head
Support plate
A
Drive pulley with sprockets to engage bubbles
To electric pick-up
Solenoids
Flexible push cables
Support plate
SECTION "A-A"

- FIGURE 3 -

PLASTIC BUBBLE FATIGUE TESTER
(By K. F. Johansen)

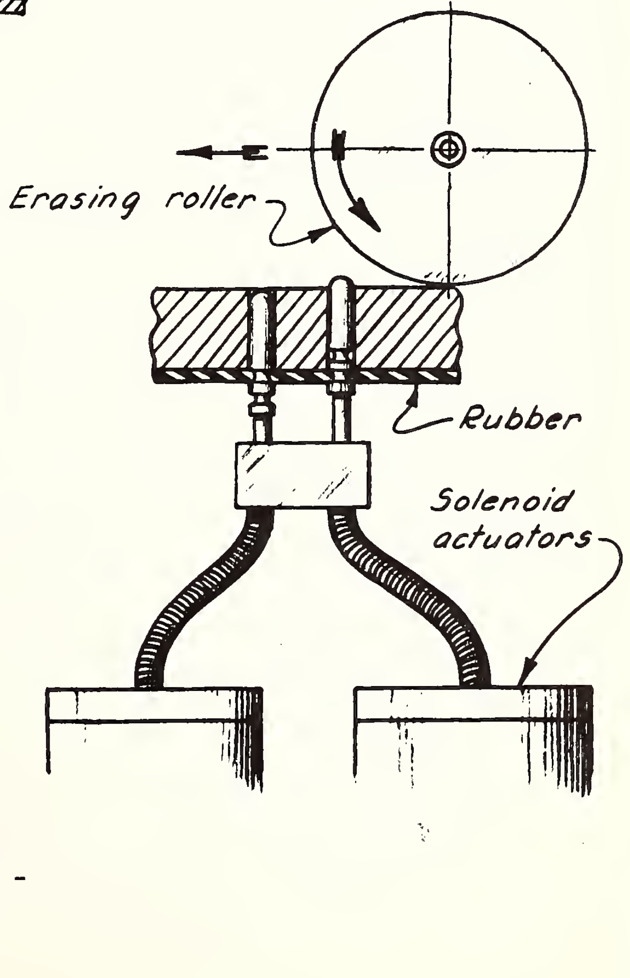


Tests demonstrated that plastic had to be very thin to last a reasonable time since the size of the bubbles is that of a braille bump (≈0.060" Dia. by 0.020" Ht.)

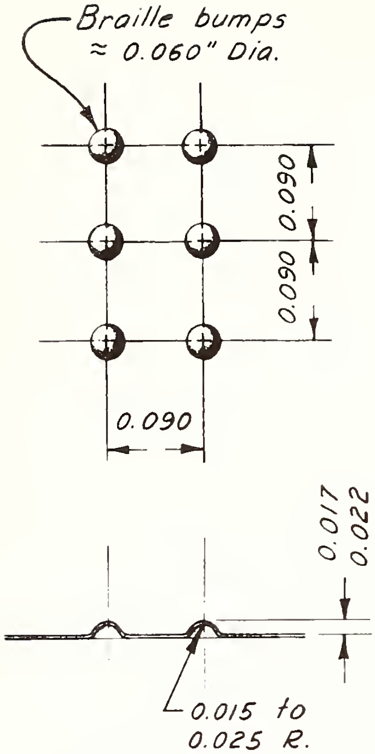


The effect of the thin plastic bubbles was inadequate, they deformed easily and stimulus was confusing.

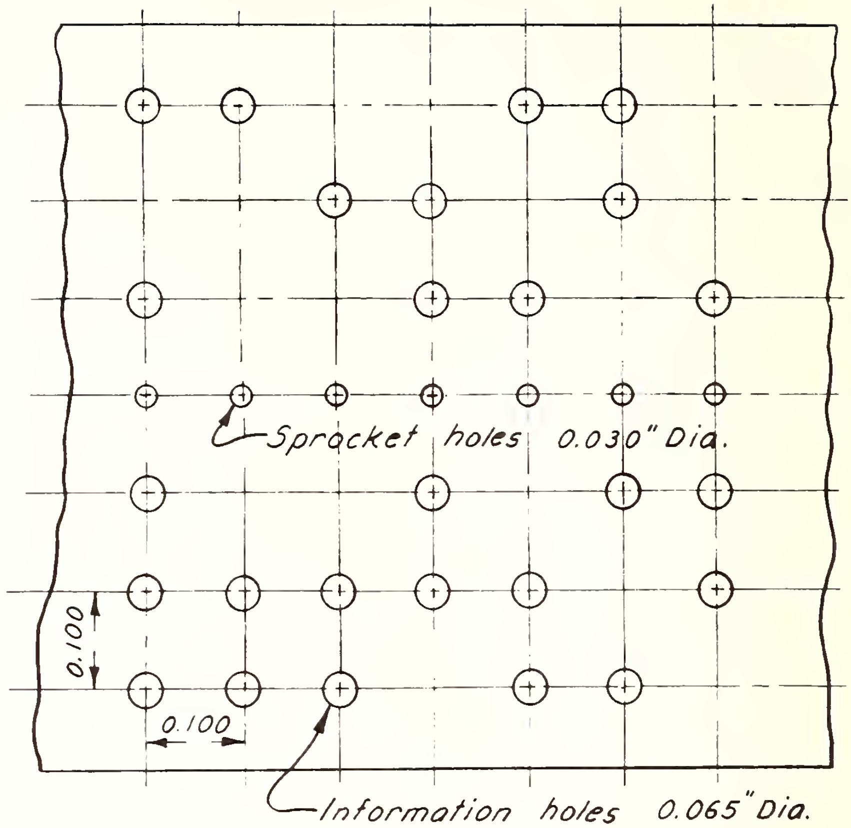
BI-STABLE PINS CONCEPT
Investigated by J. N. Wheeler et al. Various actuation systems were later investigated by others.



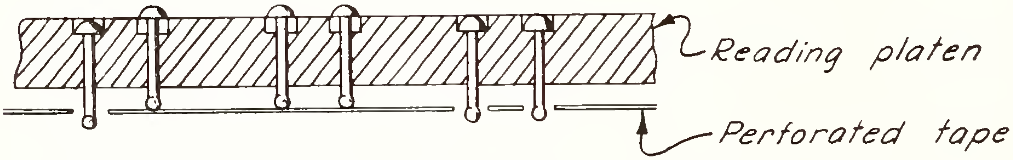
- FIGURE 4 -



BRAILLE CELL SIZE
(Size varies slightly among printing houses)



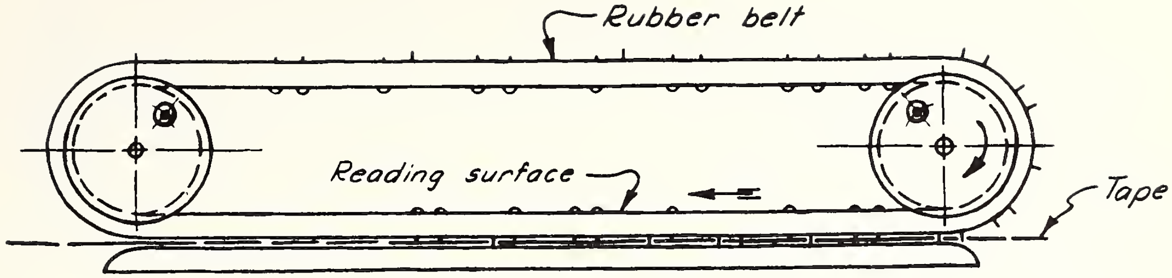
SIX TRACK PERFORATED PAPER TAPE
All holes spaced 0.100" in both directions



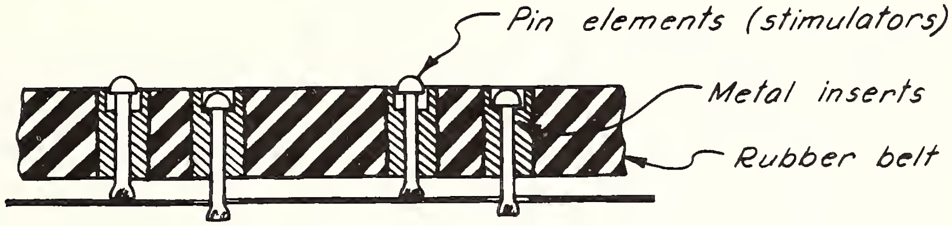
"DIRECT" TRANSDUCTION CONCEPT

The small size difference between braille bump spacings and the spacings of tape perforations suggests the possibility of direct sensing of tape holes by the tactile stimulators. This is termed "direct transduction". Tape should be perforated in "negative" braille.

- FIGURE 5 -

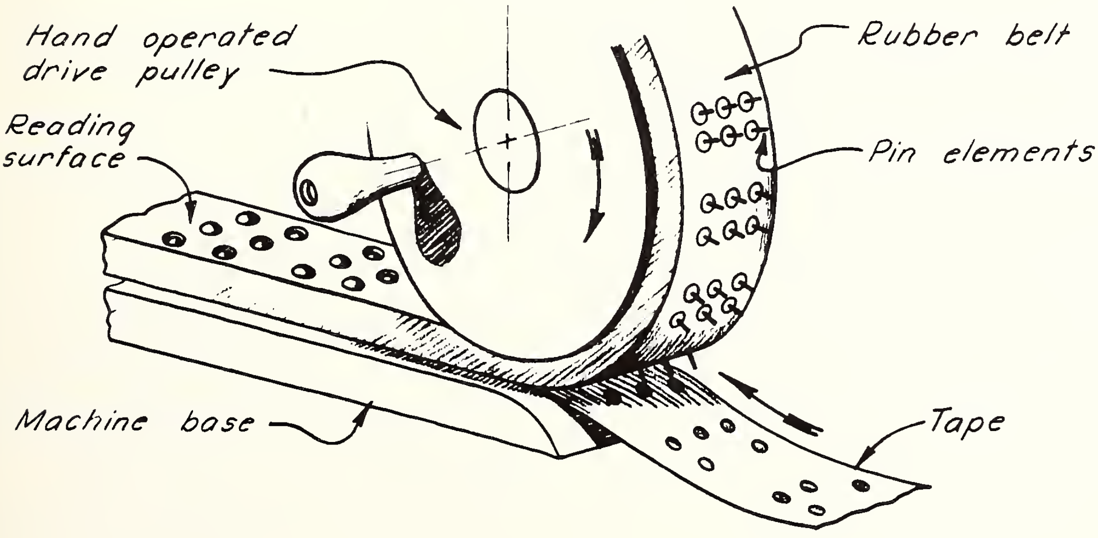


RUBBER BELT CONTINUOUS TRANSDUCER



LONGITUDINAL SECTION OF BELT

In this system the pin elements are held inside metal inserts which in turn are cast into the rubber belt that forms the continuous reading surface.



- FIGURE 6 -

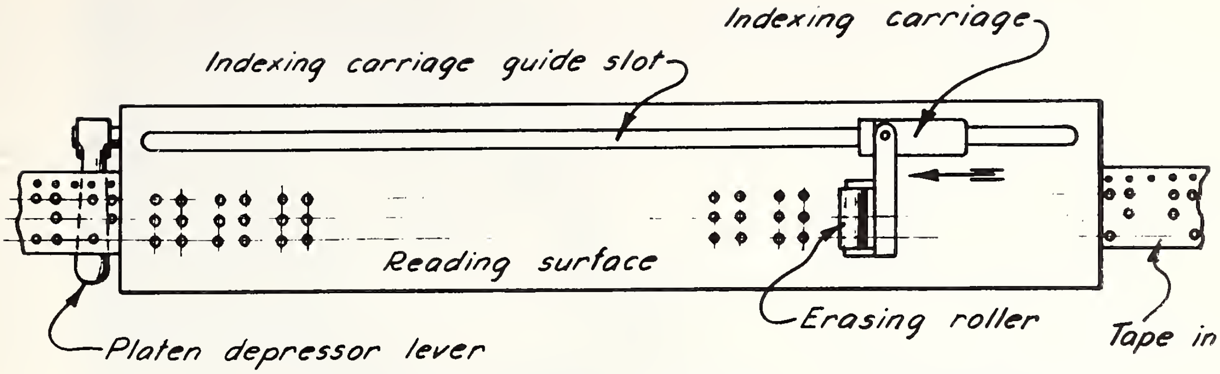
10 - INTERMITTENT OR LINE-AT-A-TIME DIRECT TRANSDUCER -

See Figs. 7&8. This machine was built by Mr. Kai F. Johansen to test the principle of direct transduction from perforated tape to braille through the use of vertically-guided gravity-fed pin elements. In this machine the tape is longitudinally positioned and then raised into contact with the pin elements. The spacing between the pins corresponds to the hole spacings on the tape. When the tape is raised, the pins directly above the tape holes penetrate into the holes and therefore remain undisturbed, their heads being below the reading surface. On the other hand the pins which do not coincide with tape holes are raised by the tape and protrude above the reading surface forming the braille "bumps". The transducer tapes are perforated in "negative braille", meaning that where a braille bump should be produced there is no hole in the tape, and vice versa. The result of bringing the tape into contact with the pins is to produce a line of raised pin heads representing a line of braille.

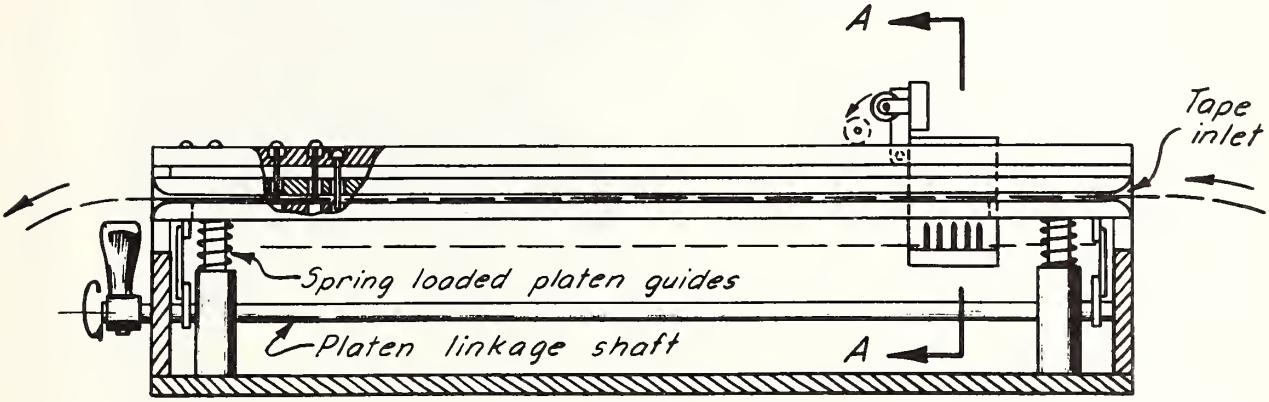
The principle could hardly be simpler in theory. In practice, however, there is need for mechanically positioning and feeding the tape in a way such that the operation of switching lines of reading be performed comfortably by the motion of only one hand.

In this prototype the feeding mechanisms were rather crude and often failed to position the tape accurately in relation to the pin elements giving rise to erratic readings. Another even more serious difficulty resulted from the inconsistency of pin spacings caused by excessive play between pins and guiding holes. The top plate supporting the pins was found to be too thin and did not provide sufficient guidance. A greater L/D ratio should have been provided.

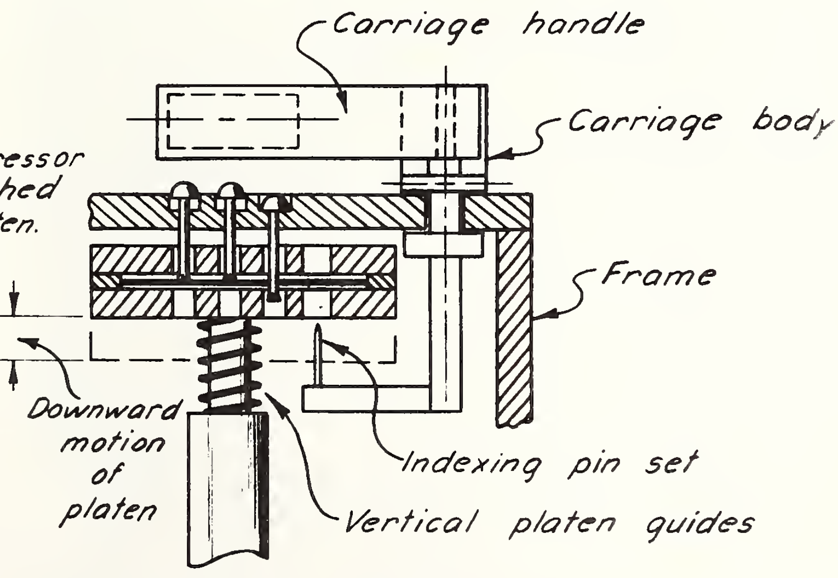
In spite of the imperfections listed above the machine served to



INTERMITTENT DIRECT TRANSDUCER
(Sketch of feasibility prototype)



INTERNAL DETAILS



To index tape the depressor lever (see above) is pushed down lowering the platen. The pin elements are thus disengaged and the indexing pins are engaged into sprocket holes on tape. The indexing carriage can then be pushed along the reading surface feeding a new section of tape.

SECTION "A-A"

- FIGURE 7 -

FEASIBILITY PROTOTYPE OF INTERMITTENT DIRECT TRANSDUCER

- FIGURE 8 -

indicate the feasibility of the system and revealed the areas of probable difficulty in a future working model. The machine also helped estimate the "feeling" that blind users could expect from the system.

Informal evaluation by blind subjects disclosed that the "bumps" seemed to move sideways under their fingers, and that their height was not constant. All of that was caused by excessive play between the pins and their holes on the top plate, and by small variations in their length caused by a crimping operation performed on the pin tips to prevent their falling off from the top plate.

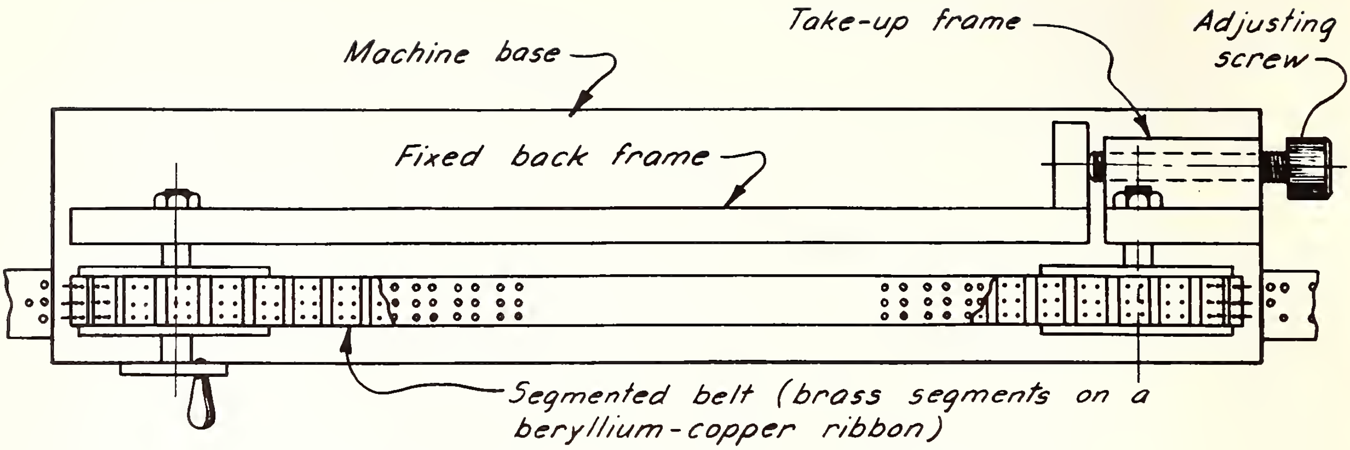
Blind subjects readily noticed the slightly larger size of the braille characters in this machine but expressed no objections whatsoever in that respect.

The operation of the mechanism used for switching the lines of reading did not meet with any strong objections, although a suggestion was made regarding the possible use of a push button at the right hand side of the machine to replace the lever and slide presently used which has to be pushed leftward across the whole reading surface to "erase" the previous line and feed the new tape section; when the lever is released it returns under the action of a spring mechanism and the new line of braille is set. The same results could undoubtedly be obtained with less effort through other means.

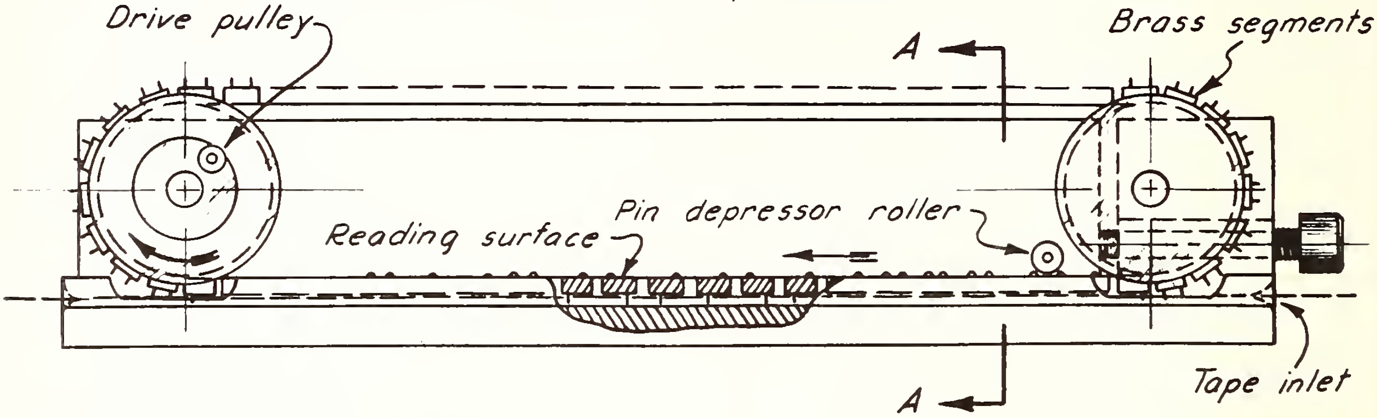
11 - CONTINUOUS DIRECT TRANSDUCER -

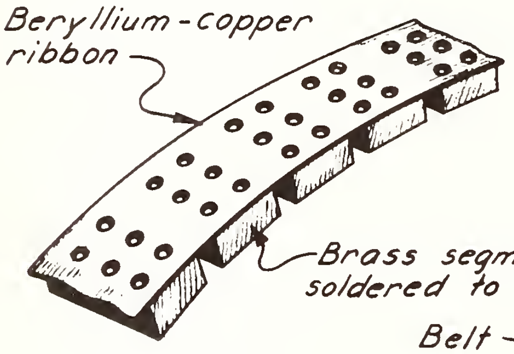
See Figs. 9&10. This machine was built concurrently with the intermittent prototype described previously. The idea was to be able to evaluate as soon as possible which machine offered the most convenient characteristics in order to orient further development efforts.

The principles of operation were essentially the same for both machines, but in the case of the continuous model the pin elements

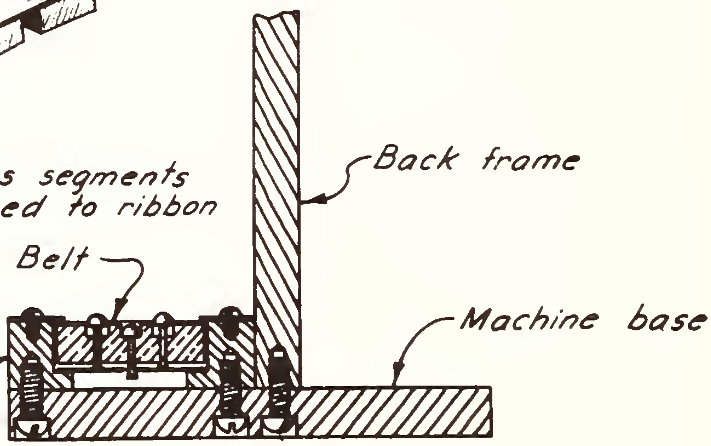


CONTINUOUS DIRECT TRANSDUCER
(sketch of feasibility prototype)





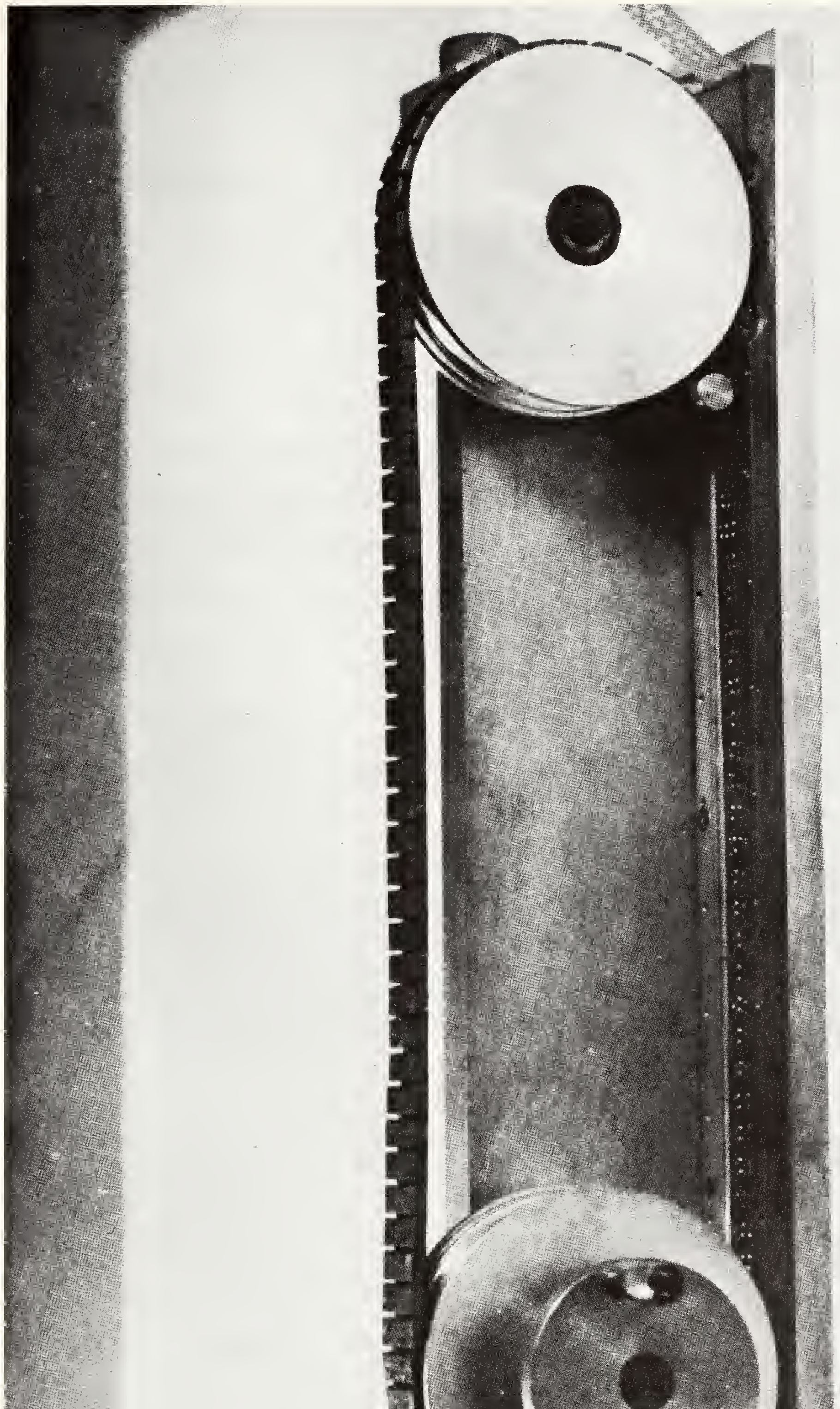
BELT DETAIL



SECTION "A-A"

In this model no provision is made for tape drive by utilizing the tape sprocket holes. The tape here is driven and sensed by the pin elements.

- FIGURE 9 -



FEASIBILITY PROTOTYPE OF CONTINUOUS DIRECT TRANSDUCER

- FIGURE 10 -

were supported by small brass segments soldered to a beryllium copper ribbon to form an endless belt. The belt itself was supported by two pulleys, one of which had a handle to operate the machine.

The tape was fed from the right side and, as the belt moved down and to the left over the right hand pulley, the lower end of the pin elements engaged the holes on the tape and pulled it in underneath the reading surface. The pins therefore were used to drive and sense the holes in the tape. The motion of the pins was identical to those in the intermittent model; those which coincided with tape holes would drop through and remain below the reading surface, and those which rested over the tape were raised above the reading surface, simulating braille bumps.

The evaluation of this machine disclosed deficiencies similar to those found in the intermittent model. The pin elements often failed to come into proper alignment with the tape holes causing erratic performance. This was considered to be the result of excessive pin play in the belt segments combined with the fact that the pins were performing the dual function of driving the tape and displaying the information obtained from it. As a result from the tape driving function the pins were subjected to a lateral force which interfered with their up and down motion and changed their theoretical spacing.

After a short time of testing it was noticed that the beryllium ribbon on the reading belt developed ridges between the segments, which indicated that the soldering operation used for attaching the segments had affected the original hard spring temper of the material. It was also found that the tape sometimes buckled and rippled, plugging the guides underneath the belt and causing the segments to be torn off from the ribbon.

To correct the deficiencies found in this model it became necessary to feed the tape very carefully and maintain it under slight tension while the machine was being operated. By so doing it was possible

to operate the machine well enough to estimate the possible advantages of the system.

Preliminary evaluation of the machine performance by blind subjects seemed to be favorable since no switching of lines was necessary as in the intermittent model, but it still remained to be determined whether the moving surface would be accepted by a majority of blind readers who are accustomed to stationary characters. Unfortunately, the reliability of the prototype was insufficient to permit accurate evaluations. It must be emphasized, however, that the purpose of this prototype was to determine the feasibility of the basic concept and to provide hard functional data for use in the design of a future working model.

12 - DESIGN OF FIRST WORKING PROTOTYPE OF THE CONTINUOUS TRANSDUCER -

The design of this machine is based on the same principles as the feasibility prototype from which it was derived, but the new design incorporates many new features intended to eliminate the imperfections found in the original model.

Assembly drawings 1 and 2 on Figs. 11 & 12 respectively describe the overall design of the machine. Figure 18 shows the completed system ready for testing.

The following improvements have been incorporated in this model:

a) The reading pins are made of medium carbon steel to permit magnetic retrieval from the perforated tape if necessary and decrease the likelihood of deformations of the long stems. The pin surfaces are chrome plated to prevent corrosion, and polished to reduce friction. The pin shanks are lightly crimped to prevent them from falling off from the supporting segments.

b) The brass segments carrying the reading pins are fitted with fixed sprocket pins at their lower surface to engage the sprocket holes on the tape, insuring positive feeding and accurate positioning between reading pins and tape holes. The profile of the sprocket pins approximates a conjugate curve to facilitate engagement into tape sprocket holes.

c) The reading belt segments have a trapezoidal cross section to increase belt traction and alignment over the pulleys.

d) The reading belt was fabricated through a low temperature brazing process to reduce the possibility of annealing the beryllium copper ribbon. The spacing between brass segments was carefully controlled by a special method of fabrication.

e) The base plate of the machine has four longitudinal grooves to provide continuous support for the tape and insure even pin head protrusion. See Figs. 13 & 14.

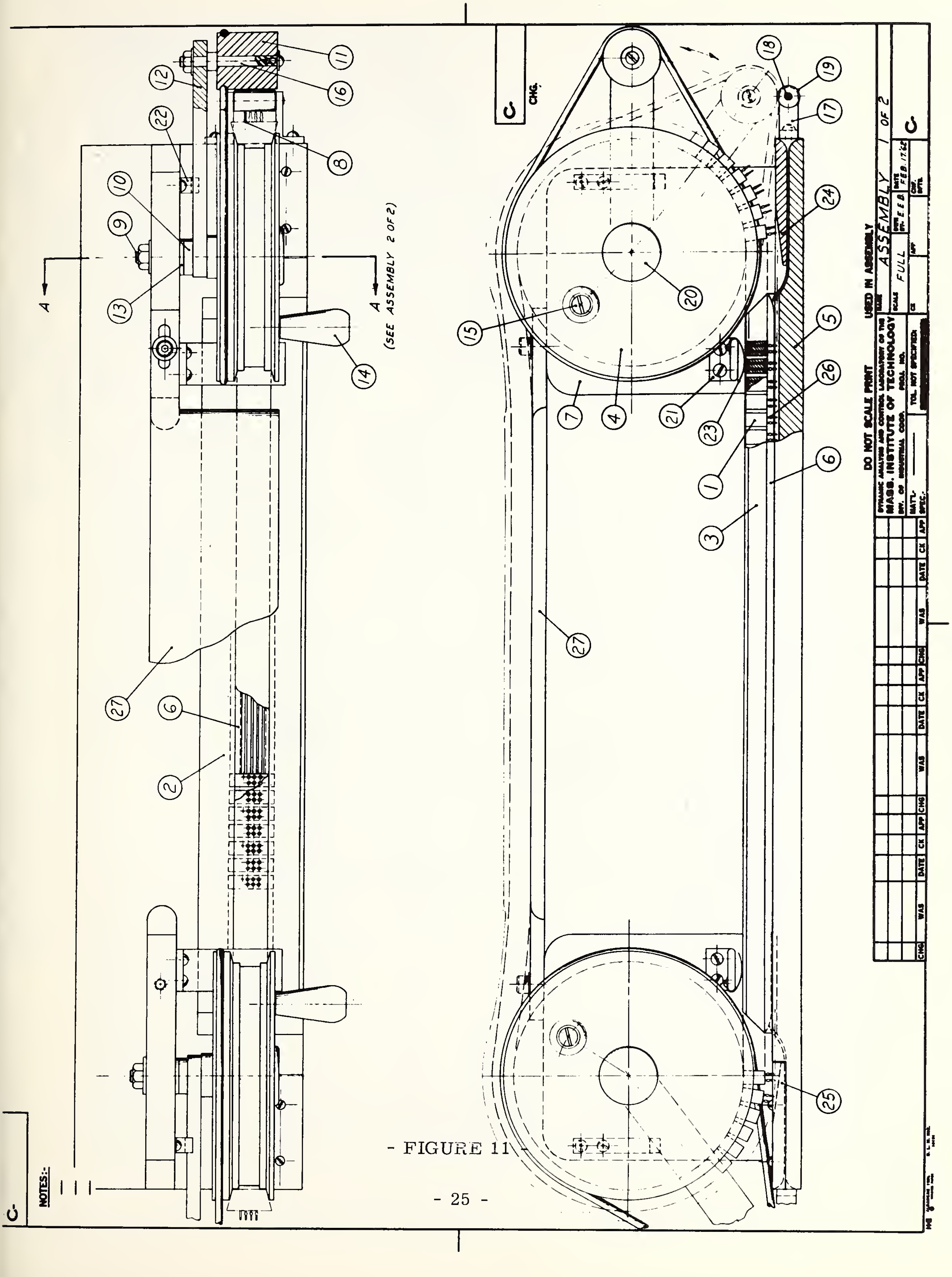
f) The pin engagement and disengagement regions are provided with tape strippers or "fingers" which insure accurate belt to tape alignment and facilitate pin retraction from tape at the outgoing end. See Figs. 15&16.

g) The upper section of the belt between pulleys is supported on a plate to reduce tensile stresses. See Fig. 17.

h) The pulleys are mounted on ball bearings with a slight preload.

i) Two rubber faced tension rollers are added, one at each end of the machine, to help keep the tape under slight tension while in operation. Only the leading roller is ever engaged in either the forward or reverse mode.

j) Handles are provided for manual operation at either pulley.



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- FIGURE 11 -

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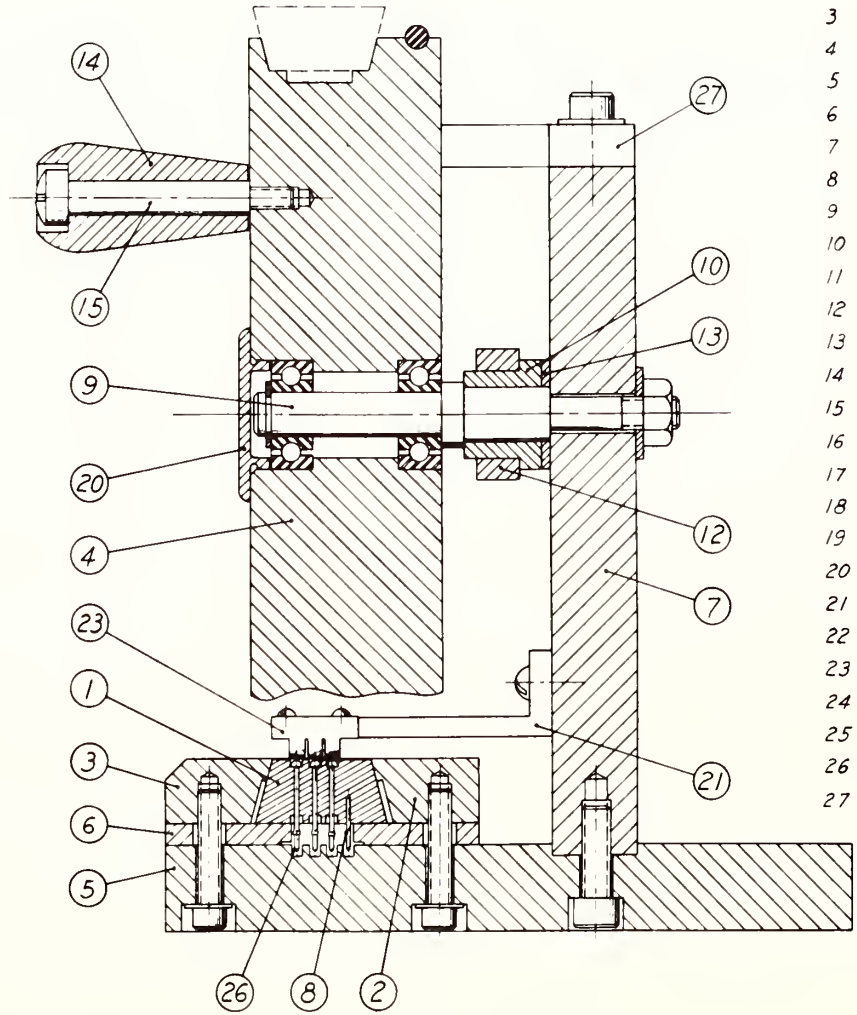

SECTION "A-A"

LIST OF DETAIL DRAWINGS

1 TRANSDUCER BELT
2 BELT GUIDE (REAR)
3 BELT GUIDE (FRONT)
4 PULLEY
5 BASE
6 SPACER
7 PULLEY STAND
8 SPROCKET PIN
9 SHAFT
10 SLEEVE
11 TENSION ROLLER
12 DRIVING ROLLER ARM
13 WASHER
14 HANDLE
15 HANDLE
16 TENSION ROLLER SHAFT
17 IDLE ROLLER BRACKET
18 IDLE ROLLER SHAFT
19 IDLE ROLLER
20 BEARING CAP
21 SPRING DEPRESSOR BRACKET
22 LOCKING SPRING
23 DEPRESSOR SPRING
24 TAPE GUIDE (RIGHT)
25 TAPE GUIDE (LEFT)
26 READING PIN
27 BELT SUPPORT

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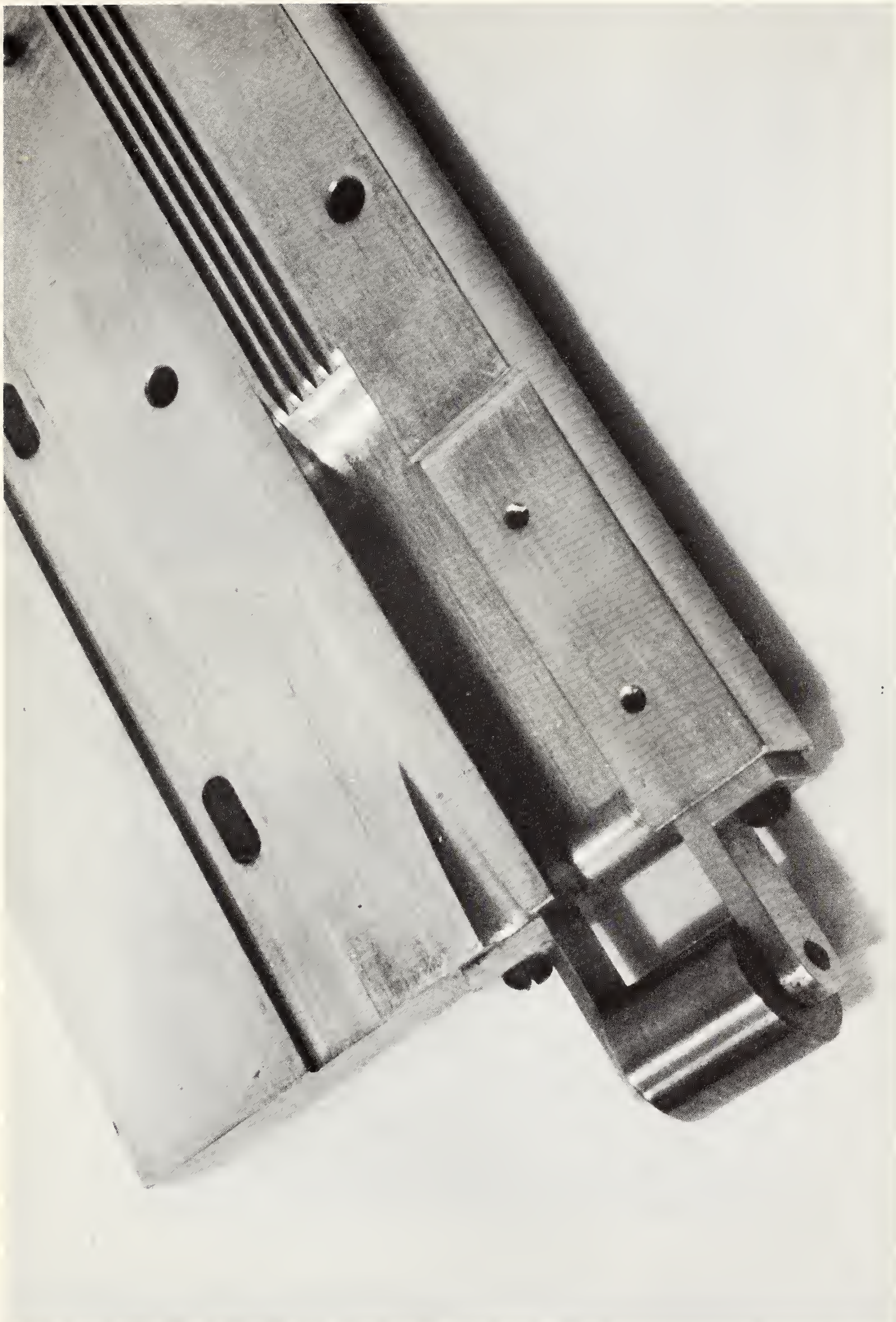
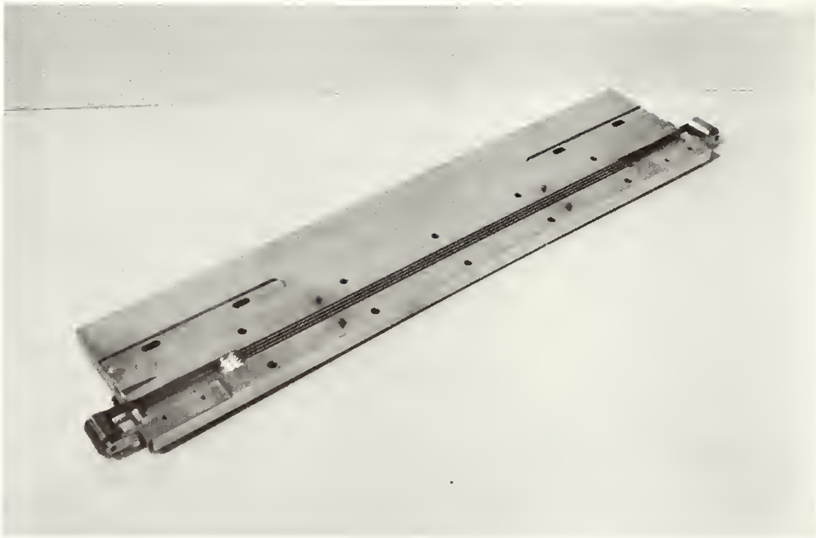
NAME: ASSEMBLY 2 OF 2
SCALE: TWICE SIZE
DWN BY: E.E.B.
DATE: FEB. 19, '62
CK
APP.
CHF. DFTS.
C-

- FIGURE 12 -



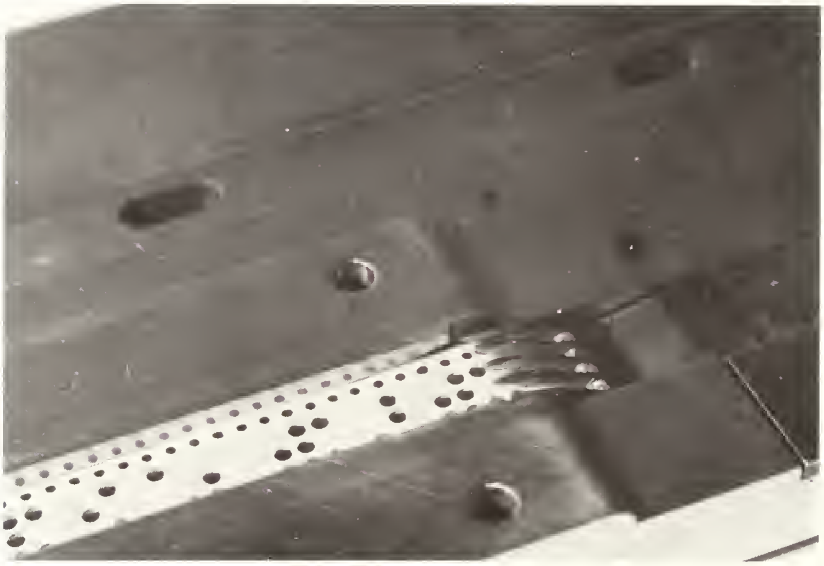
DETAIL OF BASE PLATE SHOWING LONGITUDINAL GROOVES AND TAPE STRIPPING SECTION AT OUTPUT END

- FIGURE 13 -



- FIGURE 14 -

COMPLETE VIEW OF BASE PLATE

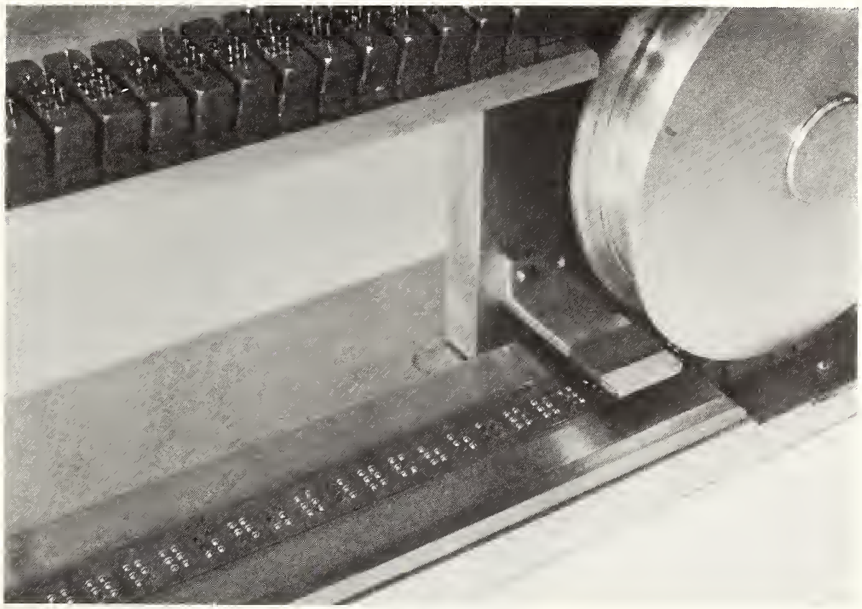


- FIGURE 15 -

DETAIL OF INPUT END OF BASE PLATE SHOWING TAPE AND STRIPPER IN OPERATING POSITION. SPACER PLATES ARE SEEN AT SIDES OF TAPE

- FIGURE 16 -

DETAIL OF STRIPPER PLATE SHOWING "FINGERS". PLATE LOCATION IS ADJUSTABLE ON ONE PLANE



– FIGURE 17 -

DETAIL OF INPUT END OF COMPLETED MACHINE IN OPERATION SHOWING PIN POSITIONS. NOTICE BELT SUPPORT PLATE AT TOP

VIEW OF COMPLETE MACHINE DURING TESTING

- FIGURE 18 -

k) All parts are provided with ample adjustment to facilitate fitting and experimentation.

NOTE - Input tapes for this machine must be trimmed to a width of 0.475 ± 0.005 in. Tape should contain three information channels plus the sprocket row of holes. A simple tape trimming device designed for this machine operates with absolute reliability.

13 - ORIGINAL FABRICATION -

With the exception of the pin carrying segmented belt, all machine parts were manufactured without need for special techniques.

The fabrication of the reading belt was specified with considerable care to avoid perturbing the hard temper of the beryllium copper ribbon.

The operation of joining the brass segments to the ribbon was done through a low temperature soldering process. The locational tolerances were maintained by machining all the segments from a solid bar of brass stock while they were still joined through a "spine" at one side. Following the soldering operation, the spine was machined off and both sides of the belt were finished. The two ends of the belt were then soldered with a low melting point alloy while the adjacent segments were provided with good heat sinks to limit the spread of heat to the rest of the belt.

The belt soldering operation was performed by an independent concern which unfortunately did not follow the rigid procedures specified. The temperature, soaking period, and jig positioning were incorrect for the job, resulting in excessive solder runout, partially filled interfaces, and recrystallization of the beryllium copper ribbon.

Since at this time it seemed impractical to fabricate a new belt it was decided to assemble the machine hoping that the belt would last throughout the testing period. As indicated previously, the finished

machine is shown in Fig. 18 .

As can be seen in the photograph only every other segment was provided with sprocket pins. This was initially considered sufficient to position the tape in proper relation to the belt segments.

14 - DESIGN EVOLUTION -

Early performance evaluation of the machine disclosed that small longitudinal discrepancies in hole spacing between different punched tapes caused total error accumulations along the reading surface in excess of the belt tolerance giving rise to erratic readings and occasional tape breakage.

Theoretically the hole spacing in punched tapes is 0.100 in. on both directions. When the input tape being used had a longitudinal hole spacing error below 0.030 in. per 12 in. of length the machine functioned adequately, but unfortunately the discrepancy found between various kinds of tapes sometimes was of the order of 0.100 in. per 12 in. When such tapes were utilized troubles developed.

Efforts to improve function by increasing the accuracy of the tape guides and tape to belt alignment did not correct the deficiencies appreciably. At this time the imperfect fabrication of the belt began to introduce new problems. Several segments had to be resoldered increasing the likelihood of inaccuracies. Finally, an attempt by unauthorized personnel to operate the machine resulted in the destruction of a large portion of the belt when a tape strip of gross oversize width was forcibly pushed through the machine. This failure served to disclose the weakness of the belt construction. It was then decided to redesign the belt to increase its strength and facilitate some lengthwise

compliance between belt segments and tape hole spacings.

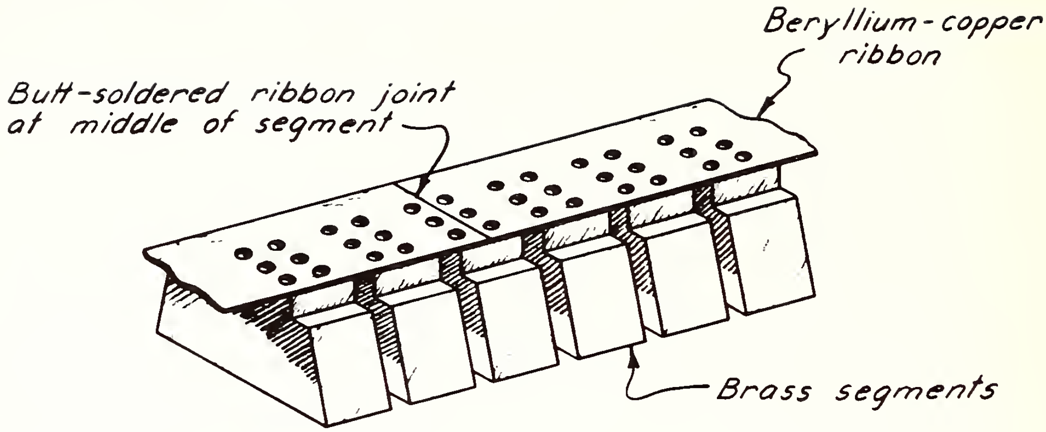
15 - WIRE SUPPORTED BELT DESIGN -

The new belt design consisted of eliminating the beryllium copper ribbon surface by threading the segments on two fine steel wires. The design is shown in Fig. 19 . The spaces between segments were maintained by means of rectangular rubber spacers kept under slight compression. This construction permitted relative lengthwise motion between segments thereby allowing the sprocket pins to position each segment in proper relationship over the punched tape. The use of wire support for the segments also facilitated adjustment of segment spacings throughout the whole belt by merely changing wire lengths at the joint. The small empty spaces between segments raised no objections from the blind readers that tried the new belt.

The improvement of the belt solved the prior problems only partially since in order to make effective joints it was necessary to fix one segment to the wires and occasional tape to belt mismatch developed around the joint region. In such construction any individual segment could slide on the wire, but the splice segment could not adapt itself to the tape hole spacings since it would be necessary for that segment to pull the wires along all other segments of the belt against high frictional resistance.

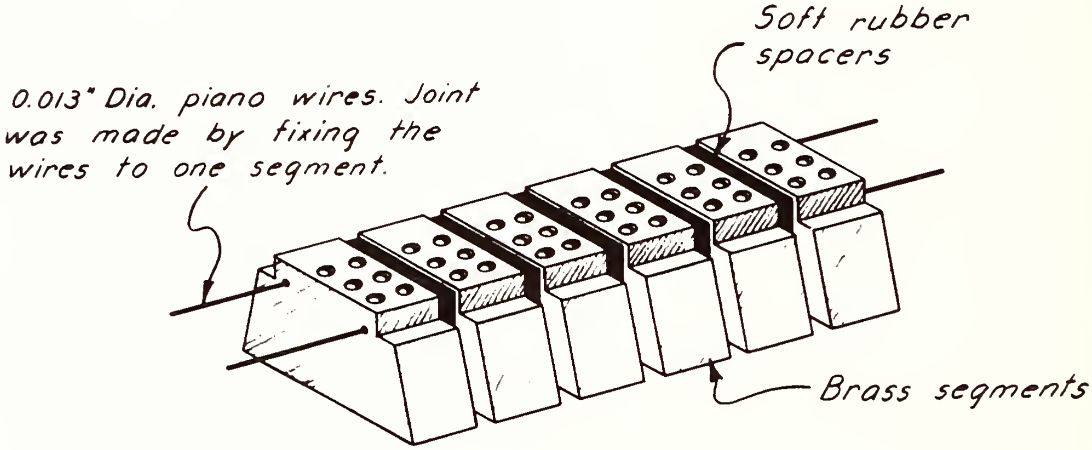
In essence the splice segment was fixed, therefore occasionally affecting reading accuracy.

An added disadvantage of the wire joint was the frequent incidence of fatigue failures. The wire material and size was selected for infinite fatigue life, but the stress discontinuities introduced by the joint made theoretical analyses and performance prediction extremely difficult.



ORIGINAL BELT DESIGN

This is the belt construction used on the first working prototype. The segments were joined to the ribbon by means of a low temperature soldering process.



FIRST BELT MODIFICATION (By John Holly)

This construction improved fatigue life and performance but the segment fixed to the wires did not permit sufficient compliance between segments and tape hole spacings.

- FIGURE 19 -

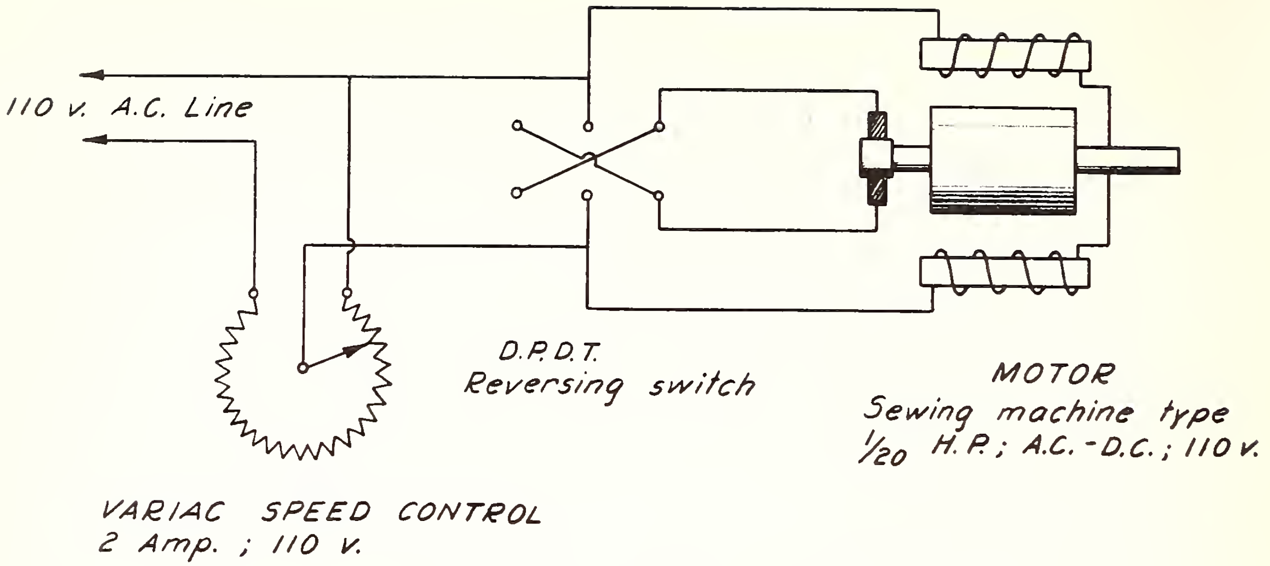
The non-homogeneity of the joint, caused by the presence of two dissimilar materials plus the silver solder interface was aggravated by the heat application, rendering theoretical fatigue analyses almost useless. It was therefore necessary to resort to experimentation in seeking for an adequate joint. Unfortunately, most every time a failure occurred a partial rebuilt of the system became necessary due to failure of other sensitive belt elements, all of which caused lengthy delays.

In spite of the aforementioned deficiencies the function of the machine with the new belt improved considerably, being capable of adequate performance even when using input tapes with greater hole spacing discrepancies than before.

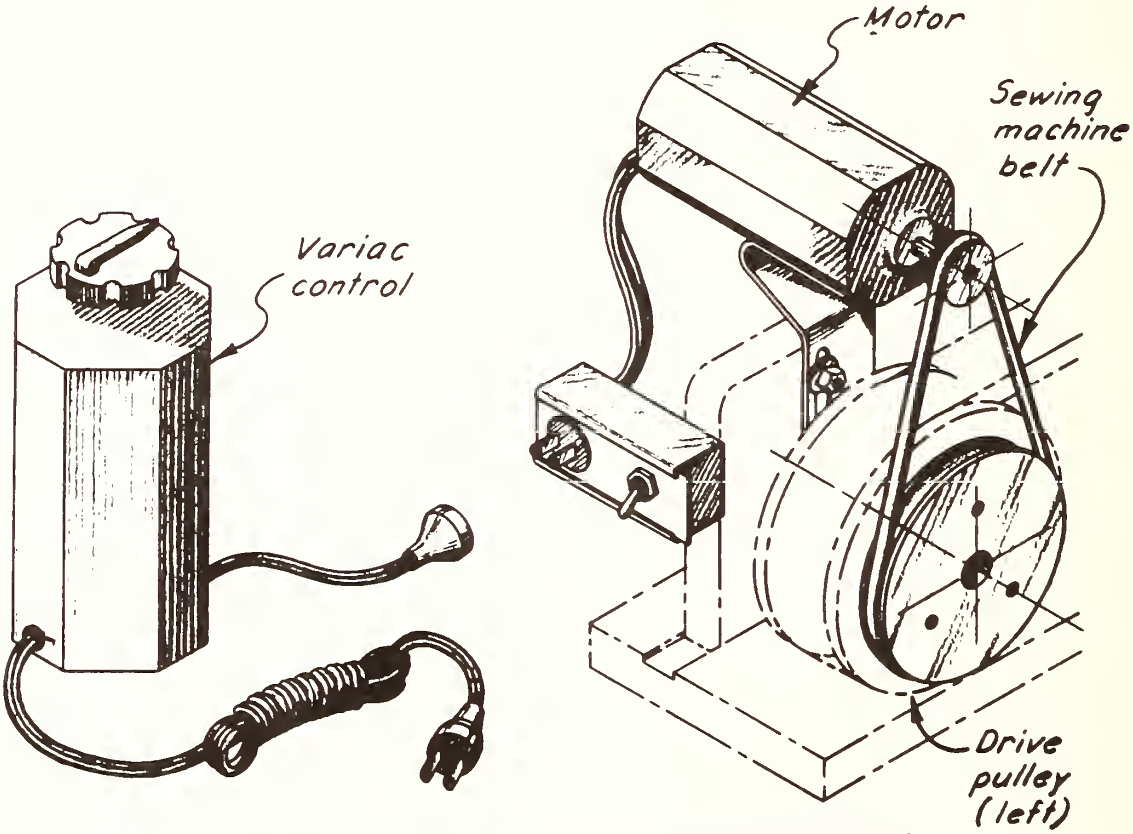
16 - FIRST MOTOR DRIVE SYSTEM -

At this stage it was decided to install a motor drive since hand operation was inconvenient and did not lend itself in the future to accurate performance evaluations. The new drive system consisted of a variable speed 1/20 HP. , A. C. - D. C. sewing machine type motor, controlled by a 2 amp. 110 v. Variac unit. The motor connections were modified for reversible operation by separating the field and armature lead wires and independently connecting them to a D. P. D. T. switch as shown in Fig. 20 . The Variac control unit served to regulate the voltage applied to the motor thereby affecting motor speed. The motor shaft was connected to the left hand pulley of the transducer through a round sewing machine type belt; the speed reduction of the drive system being 6:1 . Fig. 20 shows the arrangement of the components.

This drive system represented a substantial improvement, although at low speed, the torque characteristics of the motor were rather poor. Also, driving the whole system across the reading belt was found inconvenient since the elasticity of the new belt construction introduced a spac-



ELECTRIC DRIVE CIRCUIT
(By John Holly)



INITIAL ARRANGEMENT OF COMPONENTS
Final arrangement shown in photographs of finished model.

- FIGURE 20 -

ing differential between the entering and leaving segments due to friction along the belt guides. This effect manifested itself clearly as a phase shift between pulleys.

17 - CABLE SUPPORTED BELT DESIGN -

To correct the reliability deficiencies caused by the fixed segment at the joint it was necessary to join the wire ends solely to one another forming a joint that could slide freely across all segments. Such a joint could not be made effectively without resorting to a butt or resistance weld which would destroy wire temper and increase the probability of fatigue failures. A lap weld would be affected by similar deficiencies plus having a larger effective width which would interfere with segment sliding.

After considering numerous approaches and performing preliminary tests it was decided to abandon the wire support system in favor of fine stainless steel cables. A short rigid joint in the cable would not have as great a detrimental effect on fatigue life, and the greater surface area of the cable would permit a much more effective butt joint by merely using silver solder.

The resulting belt was much more flexible and remained in use throughout a substantial period of testing, until a failure on one of the joints indicated the necessity for an even better approach. The use of cables, however, uncovered a whole new range of possibilities. Since the cable used consisted of three strands of multiple fine wires it was decided to distribute the stresses and decrease joint rigidity, by making independent joints for each strand, each joint made at a considerable distance from the ones on adjacent strands. The new approach required the unwinding of each opposing pair of strand ends by an equal amount, and the rewinding of each strand to conform with the original

cable lay after soldering and finishing. The procedure is shown in Fig. 21 prior to rewinding the strands to reconstruct cable lay.

The new construction not only increased joint flexibility but permitted the strands to slide relative to one another thereby decreasing considerably the magnitude of the bending stresses.

To make the new type of joint it was essential to maintain exposed a considerable length of cable. To keep the cables exposed many segments had to be removed and a means had to be developed to re-insert those segments after the joint was made.

The approach used is shown in Fig. 21 . Some 20 segments were removed from the belt prior to splicing the cables. Those segments were modified by machining grooves at the sides to gain access to the holes they had previously. After the splices were made, the new "Fill-in" segments were inserted in between any two regular drilled segments. The natural stiffness of the cables and the slight compressive force between segments was enough to guarantee the permanence of those special segments on the belt.

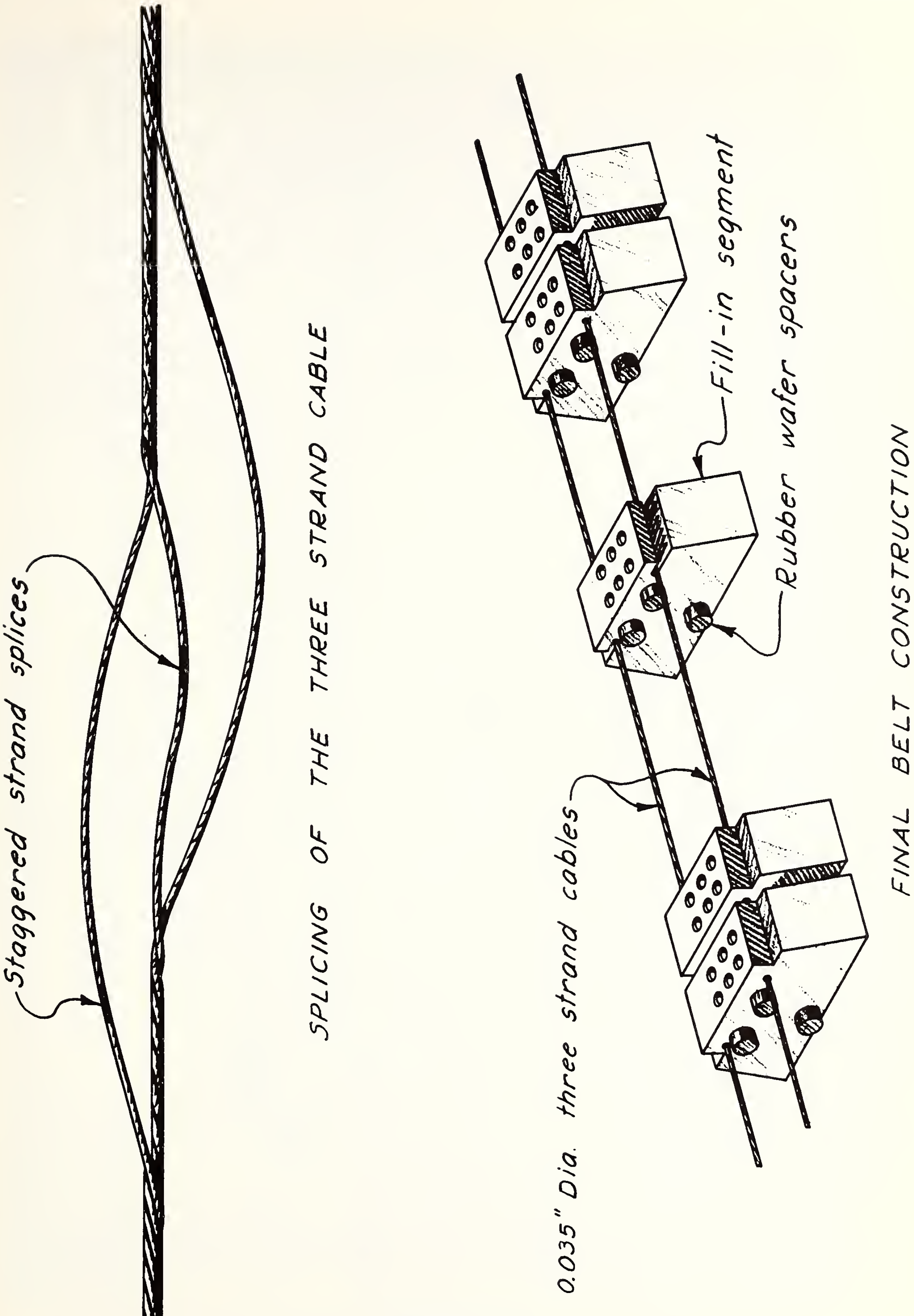
On this new belt the spacers consist of three tiny rubber wafers which insure not only proper spacing but parallelism between segments. The rubber spacers are epoxy bonded to one side of each segment.

The resulting belt construction has been in use throughout intensive periods of testing without the slightest trouble.

18 - FINAL DESIGN IMPROVEMENTS -

This stage of the development sequence consisted in refining mechanical details.

The drive unit was improved by the use of a gearmotor drive capable of high torque at low speed, and a gearbelt transmission to


Staggered strand splices
SPLICING OF THE THREE STRAND CABLE
0.035" Dia. three strand cables
Fill-in segment
Rubber wafer spacers
FINAL BELT CONSTRUCTION

- FIGURE 21 -

take the place of the previous sewing machine belt drive. The mounting rigidity of the drive system was increased by the use of stiff brackets.

The whole machine was mounted on a larger base to accommodate the large Variac unit and form a support for the machine cover and its carrying handle. See Figs. 22 and Fig.23

The Variac was fitted with a flexible control cable connecting it to a shaft located at the left side of the reading surface where the speed control knob was mounted. A rotary ON-OFF and reversing switch was mounted at the right side of the reading surface.

Between the two control knobs lies the reading surface which measures some 8 inches in length and is approximately 1 inch above the table surface. This is considered an ideal height for tactile reading. A front cover flap was added to serve as dust cover and also as a hand rest when opened.

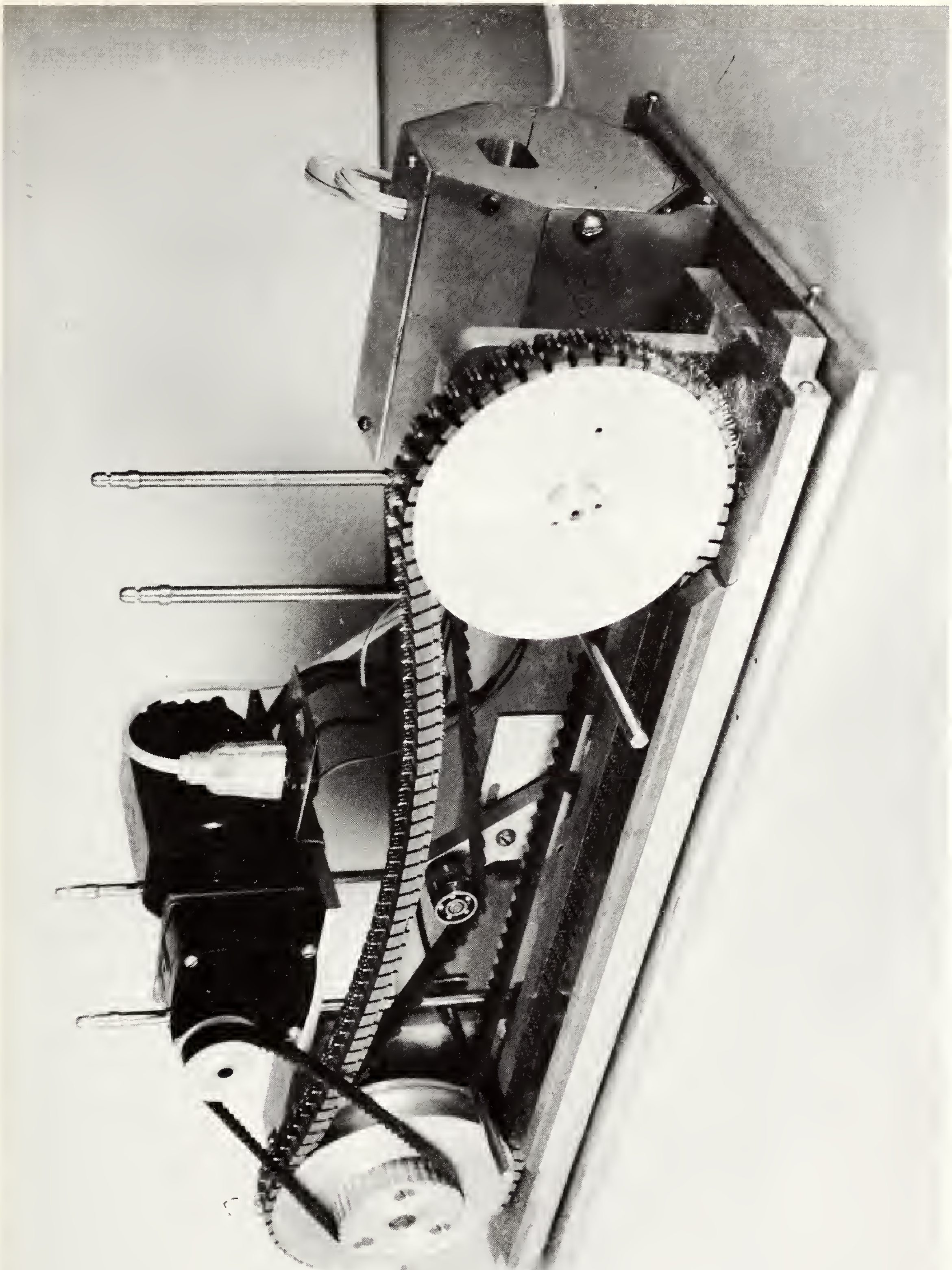
The machine function was further improved by the addition of a timing belt between the two main pulleys to maintain synchronism between the pulleys and eliminate driving tension on the reading belt. An idle roller maintains constant tension on the new timing belt.

The machine cover was made from 1/16 inch thick aluminum stock covered with a plastic upholstery material to provide a warm feeling to touch. The front panel is hinged at the top and can be easily opened by removing the two control knobs. See Fig. 26 .

The two tension rollers originally located at the sides were found to be unnecessary when the machine was operating properly and therefore were not included in this final model.

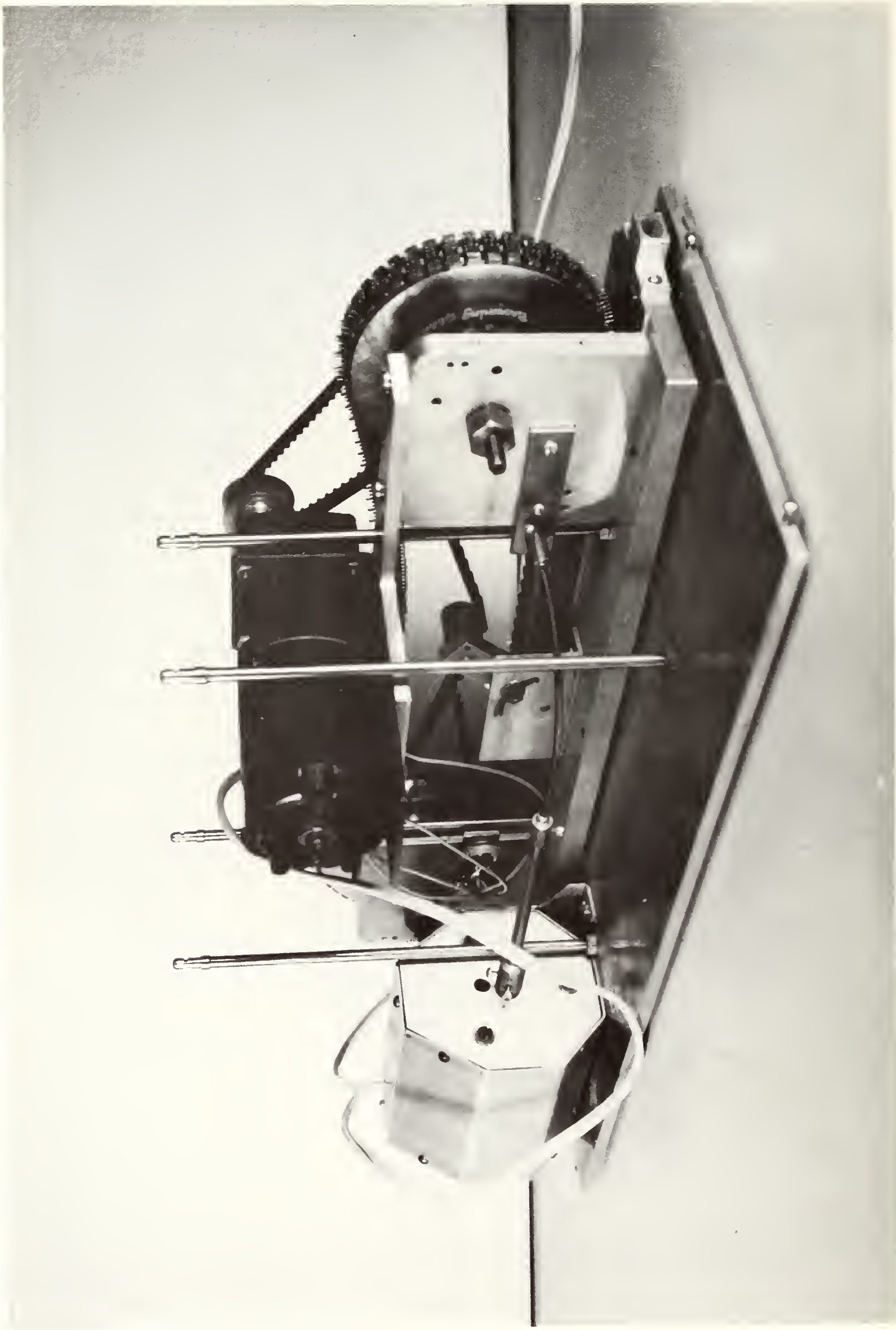
The two tape feeding openings at the ends were slightly modified to facilitate tape insertion by blind users.

Tape magazines were designed for easy tape loading at the right



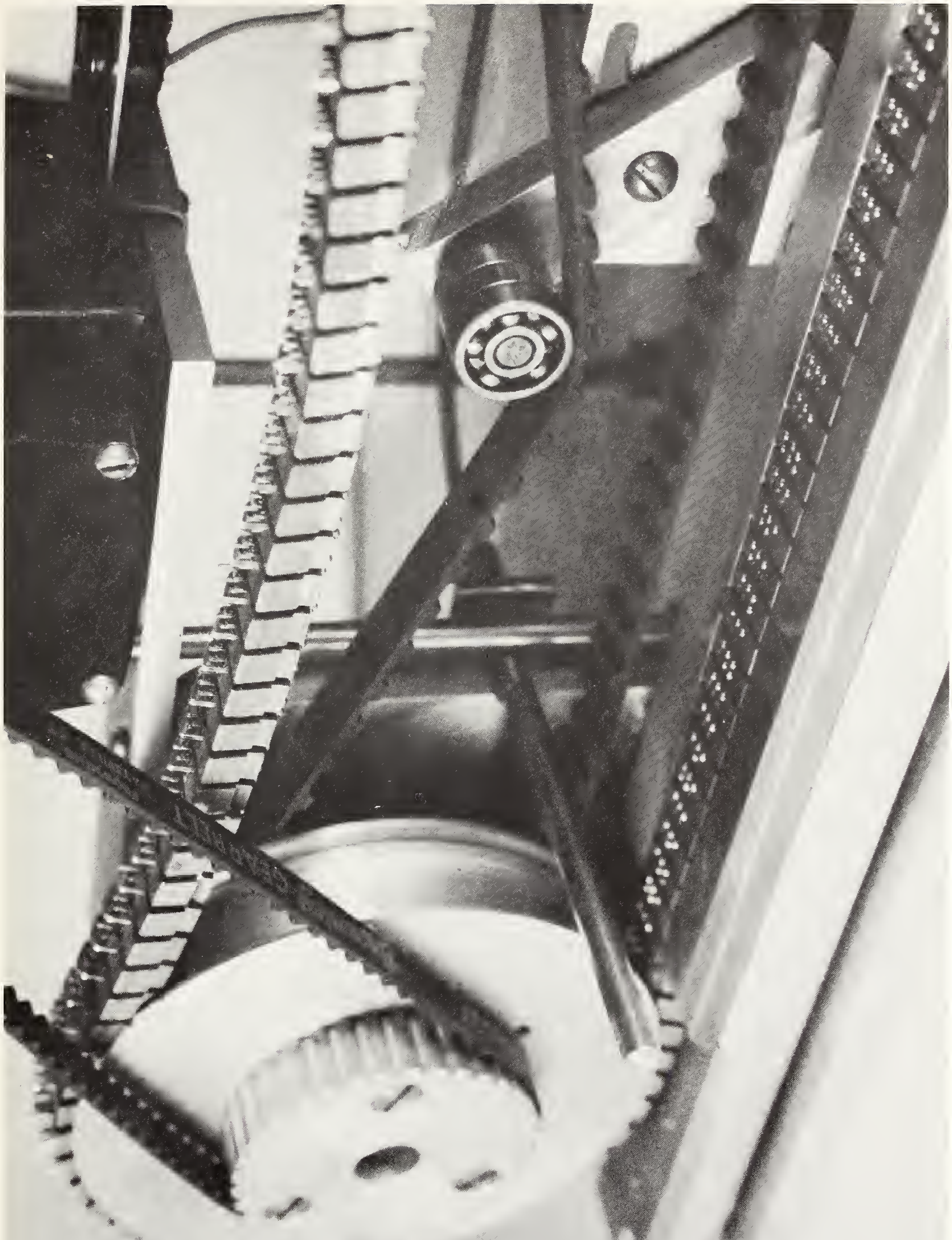
FRONT VIEW OF FINISHED MACHINE WITH COVER REMOVED

- FIGURE 22 -



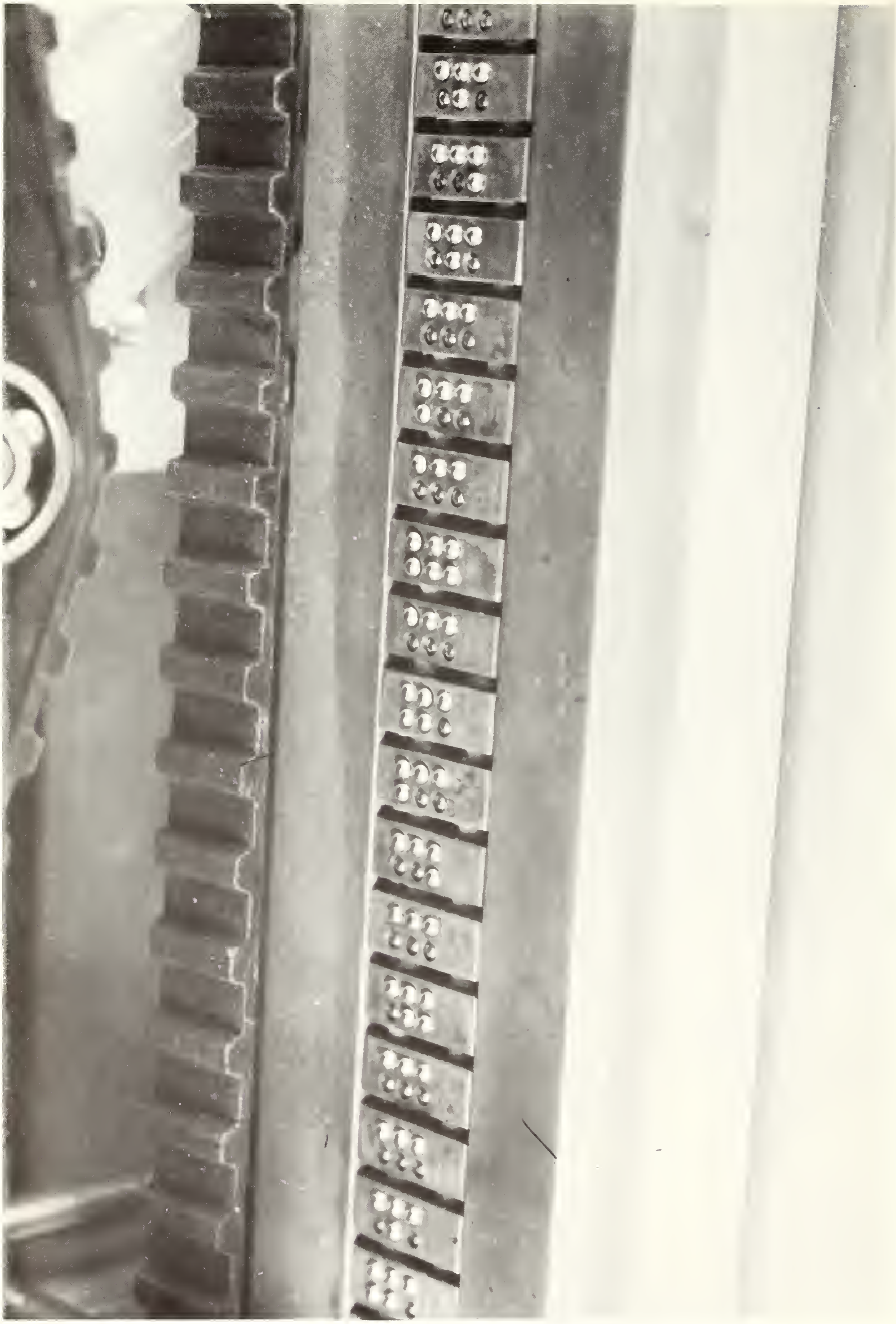
REAR VIEW OF FINISHED MACHINE WITH COVER REMOVED

- FIGURE 23 -



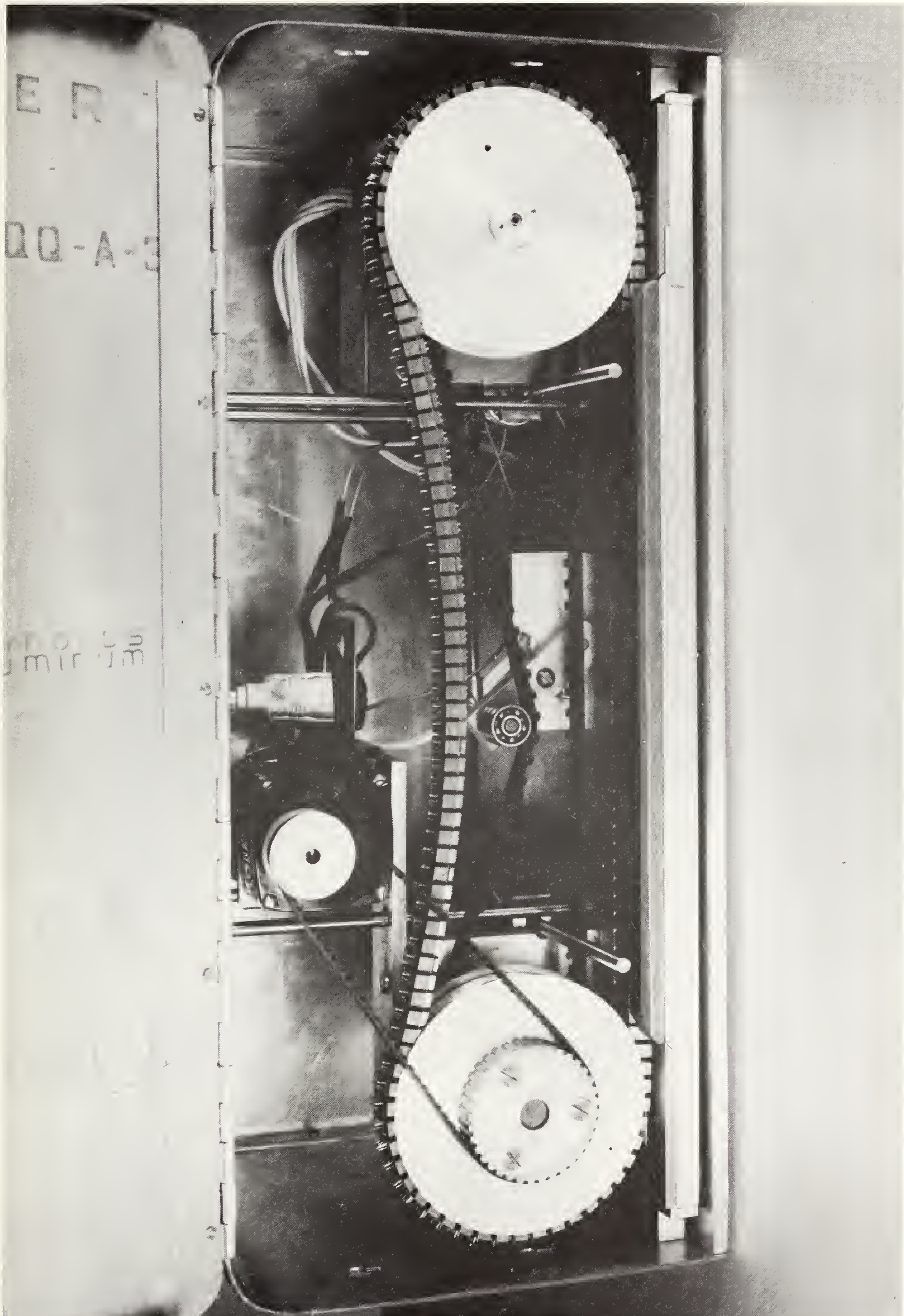
DETAIL OF DRIVE END. NOTICE TIMING BELT AND IDLE TENSION ROLLER BEHIND READING BELT

- FIGURE 24 -



DETAIL OF READING SURFACE SHOWING PIN HEAD POSITIONS DURING READING. RUBBER SPACERS CAN BE SEEN BETWEEN SEGMENTS

- FIGURE 25 -

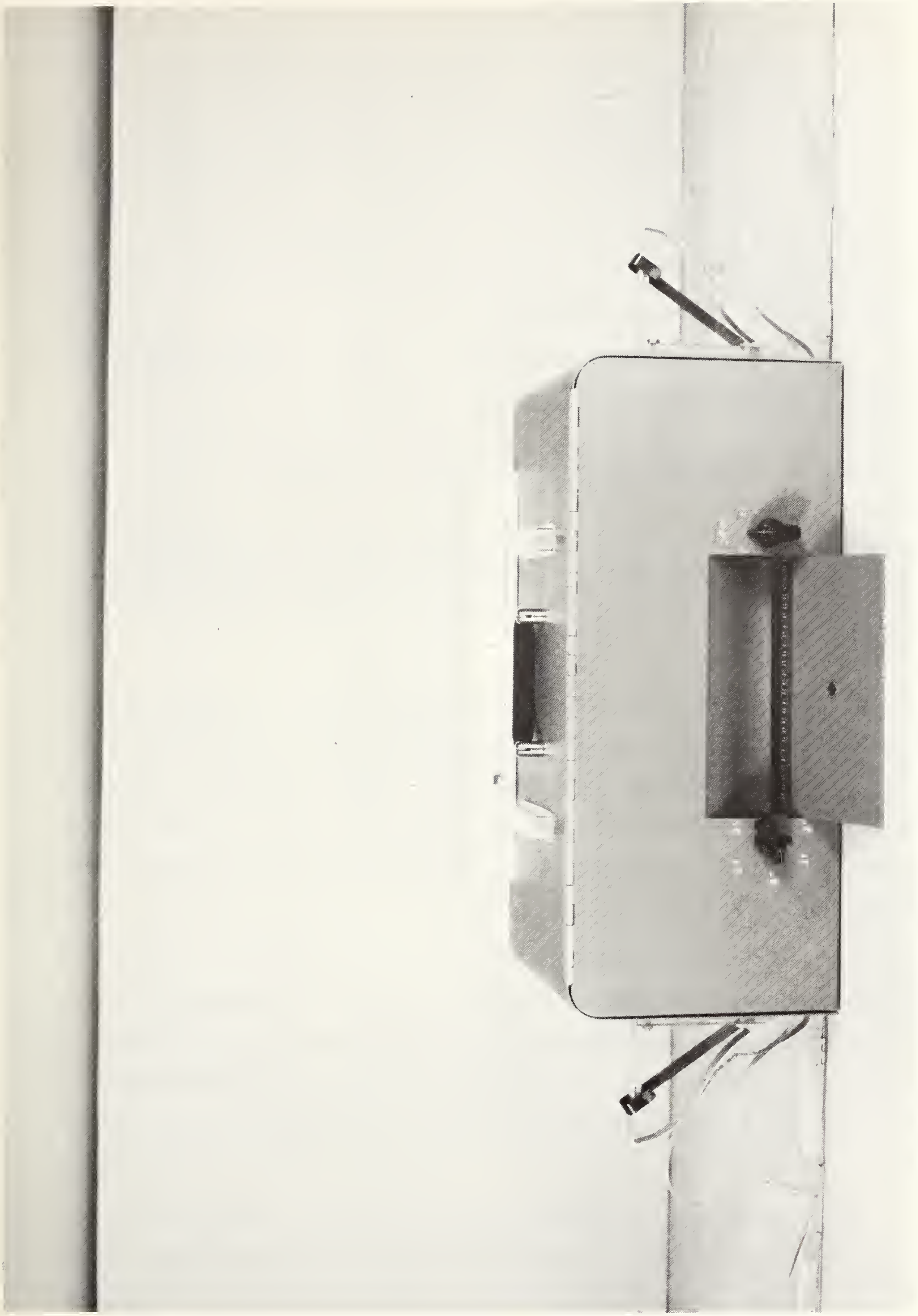


FRONT VIEW OF MACHINE WITH FRONT PANEL OPEN

- FIGURE 26 -

DETAIL OF PLASTIC MAGAZINE FOR TAPE (RECEIVING END).
SNAP-LOCK INSERTS ARE VISIBLE AT RIGHT SIDE

- FIGURE 27 -



FRONT VIEW OF COMPLETE MACHINE DURING TESTING. FRONT FLAP SERVES AS HAND REST. RIGHT SIDE KNOB IS "FORWARD-OFF-REVERSE" CONTROL. LEFT KNOB IS SPEED CONTROL

- FIGURE 28 -

end and reception at the left end. The magazines are made of plastic sheet stock and have internal tape supports and guides to facilitate tape transfer. Both tape magazines are snap-lock mounted to the cover to maintain proper alignment. See Fig. 27.

The cover has two snap-locks to permit removal without tools and is provided with a luggage type handle.

Fig. 28 shows the finished machine during a test run. The two control knobs are labeled in braille.

19 - PERFORMANCE EVALUATION -

No formal evaluation of the machine has yet been performed, although several blind readers have expressed their reactions informally.

The tapes presently available are all for Grade 1 braille and their dimensional accuracy is well within the machine limitations. Those tapes were prepared by means of the PDP-1 computer using a program described by Mr. John Holly in his B. S. Thesis.[1] Altogether some twenty test articles were put on transducer tape for future reading experiments.

Several blind subjects have operated the machine and expressed varied reactions. Older subjects have indicated some difficulty in adapting themselves to the feeling of the moving line of characters that seem to "pace" their reading speed; they have also complained about the "metallic" feeling of the reading surface which they consider too smooth, cold, and "slippery".

Blind persons have extremely sensitive sense of touch since it is through that communication channel that they compensate for their lack of sight. Their finger tips become highly refined information receptors unlike those of a sighted person; therefore, any departure from accepted

touch reading methods can easily be magnified to the point of dislike. The older the blind readers the greater their difficulty in adapting to new and different reading approaches.

It seem interesting to note, however, that none of the subjects expressed any objection to the larger size of braille cell displayed by the machine. Their reaction was one of amusement; in some cases approaching relief.

Experiments with younger blind subjects indicated their readiness to accept a different approach to braille display and understand the possible advantages of the new method.

One of the test subjects, Mr. Henry Bursch, a senior student at Tufts University, revealed after a few trials with the machine that it was not difficult to get used to the new "feeling", and expressed a desire to see the machine soon in the market. Mr. Bursch was considering to become a radio newscaster and felt that a machine such as this would enhance his opportunities enormously. His reading speed with the machine was around 120 words/min. Another student friend of Mr. Bursch could read well at 150 words/min. At faster rates of operation they claimed it was difficult to identify all words and it became questionable whether the readers or the machine were at fault. Their total experience with the machine involved less than two hours.

Mr. Bursch is a radio amateur with mechanical inclinations, and with little assistance was able to take apart the tape magazines, and the machine cover, to satisfy his curiosity. He claimed to understand perfectly the principles of operation of the system and had little difficulty reassembling the components.

Experiments at the Sensory Aids Evaluation and Development Center, in Cambridge, Massachusetts failed to disclose the true capabilities of the machine due to the use of tapes that contained longitudinal errors in hole spacing far in excess of those which the machine could

accommodate. Efforts to improve performance through modifications of the tape guides only made the situation worse, contributing to the despair of the experimenters. When the machine was again fed the proper tapes normal function was resumed, but by then the experimentation time allotted was exhausted.

The present model will function reliably with tapes having longitudinal hole spacing errors in the range between -0.020 inches to +0.060 inches for every 12 inches of length. Punched holes should theoretically be spaced 0.100 inches on both directions, across and along the tape. The tolerances listed above pertain to total permissible departure from theoretical spacing in 12 inches, which means that since an "ideal" tape should have 120 holes in 12 inches of length, the present model could operate adequately with tapes measuring from 11.980 inches to 12.060 inches along a span of 120 holes.

It must be pointed out that the tape punching systems presently in existence are capable of adjustments to a greater accuracy than is required for use in this machine. Dimensional stability of existing tapes under normally varying atmospheric conditions does not seem to pose any serious problem.

Mr. Harry Friedman of Howe Press, in Watertown, Massachusetts has also performed informal evaluations of this machine. He has indicated that, since some blind readers have difficulty in adapting to the moving characters in the continuous model, a more thorough investigation of the intermittent or line-at-a-time model might be advisable. It seems that Mr. Friedman's suggestion should be seriously considered, however, experimentation with both transducer types should be undertaken until enough reliable data is obtained and a definite preference is established.

20 - CONCLUSIONS AND RECOMMENDATIONS -

The machine described here is a working prototype in sufficiently good order to indicate the real possibilities of its basic concept and collect data for a final design in which such factors as size, weight, cost, and overall reliability could be optimized. The reliability of the present model is still open to question since it has not yet been operated for sufficiently extensive periods of time, but it seems adequate enough to permit essential tests.

The basic concept of "direct" mechanical transduction of punched tape to braille still seems the most attractive approach to keep complexity and cost at a level compatible with individual ownership of the machines. The only possible disadvantage of this system seems to be that more tape is needed than when taking the information crosswise from the tape, as in conventional usage. The transducer tapes for this machine utilize only two thirds of the information capacity of the tape since for every cell of braille displayed there is one crosswise row of holes unused between cells. It must be indicated, however, that tapes for use in direct transducers could have six channels, and be passed through the machine twice in two different positions, to read only three channels at a time; thereby using the same sprocket holes twice and making it unnecessary to use one whole narrow tape for every article to be displayed in braille. Only a minor modification of the width of the tape guides would be necessary for use of six channel tapes. In all cases the proper position and identification of the tapes is indicated by a leading section on which the title is embossed in conventional braille.

A double capacity, or six channel tape, would have two leading sections embossed in braille on opposite sides of the tape. One leading section identifies the article stored on the three channels on its side;

and the other leading section, embossed underneath and side by side to the first, identifies the contents of the adjacent three channels. Once the first three channels have been read the tape can be inverted and passed again through the machine to continue reading.

It is recommended that the present machine be modified in the future to allow tapes with greater lengthwise hole discrepancies to be used without difficulty.

It is also recommended to pursue the development of the intermittent direct transducer so that both machines be available to compare their performance on a common basis. It could well be found that the assumed advantages of a continuous reading machine such as the one described here may be outweighed by the possible simplicity, or easier acceptability, of a properly designed intermittent reading device.

The objections expressed in relation to the "metallic", cold, or slippery feeling produced by the present display system can easily be corrected by the application of a rough plastic coating on the reading surfaces; this is a minor problem in surface finish.

In a commercial model the reading segments and guide surfaces would probably be made out of a suitable plastic, in which case only the pin heads would have to be treated to provide a pleasant touch sensation.

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